A Decision Framework for Supply Chain Planning in SMEs: A QFD-ISM-enabled ANP-GP Approach

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This article proposes a methodology for supply chain planning in small and medium enterprises (SMEs). The proposed framework integrates the use of selected well-proven techniques such as quality function deployment (QFD), interpretive structural modeling (ISM), analytic network process (ANP), and zero one goal programming (ZOGP) to incorporate conflicting supply chain objectives and interrelationships among various critical success factors to identify business requirements that enable supply chain planning in SMEs. The use of an integrated approach can benefit: a) QFD can help SMEs to opt for planning and translating business needs (internal or external) into measurable supply chain technical requirements. (2) ISM offers an opportunity to establish interrelationships between business needs and supply chain requirements. (3) The direct utility of ISM results in real-life decision making is complex. Complementary use of ISM and ANP improves the utility of findings. (4) ZOGP methodology incorporates goals such as cost, flexibility, lead time, inventory levels, and so on. It is expected that the proposed decision framework will help SME managers to improve the decision making used in managing their supply chain and will help SME firms to explain the basis of their decisions to other supply chain partners, specifically, OEM (original equipment manufacturer) organizations in which less bargaining power exists. This article provides an illustrative application of the proposed methodology as used by short blasting equipment manufacturer SMEs.

Keywords: supply chain management, small and medium enterprises (SMEs), goal programming, analytic network process (ANP), quality function deployment (QFD)

Introduction

The recent development of supply chain initiatives that focus on linking, integration, collaboration, and so on attempts to widen the spectrum of operations efficiency to include not only the internal manufacturing operations, but also upstream and downstream operations (Olhager, 2003). Chikán and Gelei (2010) showed that Hungarian companies in the manufacturing industry possess a well-developed capability base as far as production competence is concerned but that they could not effectively internalize adaptation and supply chain management competence and make them the sources of their increased operational performance. The present competition has even not exempted SMEs from focusing on the effectiveness of supply chain planning. The growing importance in the literature about understanding supply chain issues
specifically affecting SMEs (e.g., Arend & Wisner, 2005; Morrissey & Pittaway, 2006; Hong & Jeong, 2006; Thakkar et al., 2008, etc.) and limited contributions on decision methodology are the prime motives behind investigating the issues in this research.

Contemporary research focuses on the domain of supply chain needs of SMEs. For example, Arend and Wisner (2005), Halley and Guilhon (1997), Hvolsby and Trienekens (2002), Quayle (2003), Gunasekaran and Ngai (2003), Hong and Jeong (2006), Morrissey and Pittaway (2006), William (2006), Lenny Koh et al. (2007), Vaaland and Heide (2007), Faisal et al. (2006), Carlsson (2008), Baki and Murat (2009), and so on have provided a foundation for research in the domain of supply chain complexities in SMEs. Research on factors affecting the growth of SMEs has focused primarily on entrepreneurial personality, organization development, functional management skills, and sector economics (Chaston, 1998; Wijewardena & Tibbits, 1999). An evaluative review of the literature uncovers the following research gaps (RGs):

**RG1.** The present decision-making frameworks and algorithms are more suitable for large organizations and describe the need for proposing quantitative models that work under the constraints and characteristics of SMEs.

**RG2.** SMEs consider changes in business strategies, objectives, and requirements of effective supply chain planning as activities of two parallel lines.

**RG3.** Often decision frameworks are composed only of a collection of evaluation criteria about past mistakes without having incorporating a vision of the future. Evaluation of the cause and effect of past mistakes is often missing. This is because of the lack of awareness of driver-dependent relationships (leading-lagging indicators) in organizational objectives.

To meet these challenges, this article proposes a novel decision methodology for determining supply chain requirements that should facilitate SME business decision making. The overall methodology can be explained in two parts. The first part includes the use of QFD and ISM, which are mainly enabling techniques. The outcomes of the first phase are useful in the second phase for determining the priorities of supply chain decisions using analytic network processes (ANPs). The priority outcomes are considered as an input for the formulation of zero one goal programming (ZOGP). In addition, the following reasons further justify the utility of the proposed approach:

- **SMEs with weak negotiation power find themselves working with one-sided business decisions generally posed by large organizations. In addition, each SME has different supply chain requirements that are heavily based on its customer requirements. QFD will help SME managers to link their business priorities with customer requirements to understand the criticality of various supply chain requirements.**

- **ISM is a well-established methodology for identifying and summarizing relationships among specific items that define an issue or problem and help to impose order and direction on the complex relationships among the elements of the system.**

- **ANP is a comprehensive decision-making technique that has the capability of including all the relevant criteria - tangible and intangible (knowledge, experience, and perceptions of experts) - without bothering about their linear hierarchy in arriving at a decision.**

- **Specifically, a combination of ISM and ANP is attractive in the way that ISM can satisfy the input requirements of ANP and hence the output of ANP results can be derived in a more reliable manner.**

This article is organized as follows. Section 2 explains various supply chain conflicts in general and specifically in the context of SMEs. This helped to define constructs and criteria for the formulation of our model. Section 3 includes an illustrative application of the proposed decision framework. Finally, section 4 summarizes the contributions of the article and the implication of the proposed decision framework.

**Construct Definition and Model Conceptualization**

New and Payne (1995) described supply chain management as the chain linking each element of the manufacturing and supply processes from raw materials to the end user, encompassing several organizational boundaries, and treating all organizations within the value chain as a unified virtual business entity. Since the 1990s there has been much research on issues such as supplier integration, JIT use, supplier relationship management, customer relationships, collaborative planning, joint inventory planning, and so on. Many supply chain models and frameworks were proposed to link their crucial role in overall strategic corporate planning. Despite the existence of such a broader knowledge base, SCM has remained an area of concern for the supply chain. The literature reports a lack of evidence for the use of such knowledge in the context of SMEs. A summary of selected contemporary research about supply chain planning issues of SMEs by Huin et al. (2002), Arend and Wisner (2005), Vaaland and Heide (2007), and Harland (2007) is presented.
Huin et al. (2002) reported an empirical study on the internal supply chain planning needs of southeast Asian manufacturing SMEs. The key findings include the following:
1. Low levels of organizational hierarchy facilitates SCM deployment.
2. The closeness of the SME management to its customers and suppliers has important bearing and contributes to the accuracy and reliability of the supply chain.
3. Production forecasts for SMEs can be generated fairly accurately independent of the large corporations.
4. The deviation of actual production against planned production is significant and is found in two forms: the actual finished goods produced and the quantities produced.
5. High staff turnover heavily disturbs the internal supply chain function.
6. Blurred operational and tactical levels make balancing a supply chain network difficult.

Arend and Wisner (2005) evaluated a strategic fit between SMEs and SCM using an empirical study of 200 SMEs from the United States, Mexico, and Europe. The key findings of the study are as follows:
1. SCM has a significant negative association with SME performance.
2. Better performing SMEs may engage in SCM; SCM is not a good fit for SMEs on several performance measures.
3. SME performance is positively associated with the greater relative importance of a set of partner selection criteria.

Vaaland and Heide (2007) showed that SMEs consider the financial control and budgeting system as being most important for maintaining competitiveness while the production management system and e-solutions with suppliers are of medium importance. Simulation and scenario analysis systems received the least important rating.

Harland (2007) explored barriers to SC information integration in 19 UK-based SME units. The key findings of the study are as follows:
1. SMEs adopt e-business according to the customer dominance.
2. SMEs consider e-adoption in conflict with their strategies. E-adoption demands a complete business processes reengineering which may have a conflict with SMEs operating procedures and cost considerations.
3. The mutual loyalty among members of the SME cluster makes them reluctant to break with tradition, explore new suppliers and markets, or try using e-business to search for alternate sources.

The proposed decision framework (see Figure 1) has addressed the problem of selecting supply chain planning requirements in consideration of predetermined business goals and constraints. The decision framework can be divided into two major phases. In the first phase, an HOQ (house of quality) is constructed using an ANP approach, and in the second phase, ANP results are integrated with a
Table 1

Key house-of-quality (HOQ) development elements and their significance

<table>
<thead>
<tr>
<th>Elements</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer needs (WHATs)</td>
<td>Highlight business characteristics that should be paid attention to. For the present research, the criteria considered for this category are various supply chain CSFs.</td>
</tr>
<tr>
<td>Product technical requirements (PTRs) (HOWs)</td>
<td>Determine how well the company satisfies the customer needs. The customer needs tell the company what to do and the PTRs explain how to do it. The proposed decision framework incorporates this as various business requirements (BRs).</td>
</tr>
<tr>
<td>Relative importance of the business needs</td>
<td>The company should trade off one benefit against another and work on the most important needs while disregarding the relatively unimportant ones.</td>
</tr>
<tr>
<td>Relationships between WHATs and HOWs</td>
<td>Indicates how much each supply chain CSF affects each business need. The relationship can be presented in either numbers or symbols.</td>
</tr>
<tr>
<td>Inner dependence among the business needs</td>
<td>These needs can be identified by a correlation matrix emphasizing necessary trade-offs.</td>
</tr>
<tr>
<td>Inner dependence among the supply chain requirements</td>
<td>HOQ's roof matrix is used to specify the various CSFs that have to be addressed collateral, providing a basis to calculate to what extent a change in one feature will affect other features.</td>
</tr>
<tr>
<td>Overall priorities of the supply chain requirements and additional goals</td>
<td>Results obtained from the preceding steps are used to calculate a final rank order of HOWs, also called PTR ratings.</td>
</tr>
</tbody>
</table>

Figure 2

ISM steps for determining interrelationships among supply chain planning variables and business objectives

**STEP I: SELF-STRUCTURAL INTERACTION MATRIX (SSIM)**

The SSIM establishes a contextual relationship of “leads to” between criteria affecting the supply chain planning and business objectives for SMEs. Four symbols are used for the type of relationship that exists between two subvariables under consideration: V for the relation from i to j but not in both directions; A for the relation from j to i but not in both directions; X for both direction relations from i to j and j to i; and O if the relation between the variables does not appear valid.

**STEP II: REACHABILITY MATRIX**

The SSIM has been converted into a binary matrix, called the initial reachability matrix (IRM) by substituting X, A, V, and O by 1 and 0. For example, if criteria i leads to criteria j and criteria j leads to criteria k then criteria i must lead to criteria k. The process of bridging these gaps is known as a transitivity check. The various possibilities are summarized as follows.

<table>
<thead>
<tr>
<th>Entry in SSIM (i, j)</th>
<th>V</th>
<th>A</th>
<th>X</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry in reachability matrix (i, j)</td>
<td>V</td>
<td>A</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td>Entry in reachability matrix (j, i)</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Entry in reachability matrix (j, i)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

**STEP III: LEVEL PARTITION AND CANONICAL MATRIX**

From the reachability matrix, the reachability set and antecedent set Warfield, 1974) for each criterion is found. The reachability set consists of the element itself and other elements to which it may reach, whereas the antecedent set consists of the element itself and the other elements, which may reach to it. Then the intersection of these sets is derived for all elements. The element for which the reachability and intersection sets are the same is the top-level element. The whole process of partitioning is based on establishing the precedence relationships and arranging the elements in a topological order. Then the reachability matrix is converted into the canonical matrix format by arranging the elements according to their levels.

**STEP IV: CLASSIFICATION OF VARIABLES**

Different criteria have to be classified into four sectors, namely autonomous, dependent, linkage, and driver/independent, based on their driver power and dependence. Quadrant-wise characteristics of these sectors are given as follows:

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>First</th>
<th>Second</th>
<th>Third</th>
<th>Fourth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature of variable</td>
<td>Autonomous</td>
<td>Dependent variables</td>
<td>Linkage</td>
<td>Driver variables</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Weak dependent power and weak driver power</td>
<td>Weak driver power and strong dependence</td>
<td>Strong driver power and strong dependent power</td>
<td>Strong driver power and weak dependence power</td>
</tr>
</tbody>
</table>

**STEP V: DEVELOPMENT OF DIGRAPH**

From the canonical matrix form of the reachability matrix the structural model is generated by means of vertices or nodes and lines of edges known as a directed graph or digraph. Next, the element descriptions are written in the digraph and called ISM.

Robustness of the proposed algorithm

1. It allows users to incorporate subjective judgments for tangible and intangible issues and hence the effect of the human factor on the performance of the operational process is not totally neglected as generally is the case with quantitative models.

2. Approaches selected are well established and a sufficient knowledge base exists to avoid difficulties in defining various interfaces.

3. The proposed integrated approach is quantitative and explanatory and hence can be used to predict the output of the performance of the process as a function of process characteristics, process states, and inputs to the process.

4. The proposed conceptualization adequately includes interrelationships (using ISM), the hierarchical nature of the problem (using ANP), interlinking upstream and downstream issues (using QFD), and prioritizing conflicting goals (using ZOGP), which helps to describe statics and dynamics of processes.

5. Constructs included are based on an extensive review of literature, findings of contemporary research, and data collected through real-life case study research that includes many aspects of the processes that are relevant for explaining the behavior and actual performance of the process.

Figure 3
Salient features of the developed framework

ISM
- Identifies interrelationships among SME business requirements (BRs)
- Identifies interrelationships among SME supply chain CSFs
- Clarifies driver-dependent relationships for these relationships
- Digraph representation offers more reliable input for ANP model formulation.

ANP
- Prioritization of SME SCM CSFs
- Each stage determines priorities for various customer requirements and hence thoroughly ensures stipulated needs by large customers.
- Enables the decision maker to include tangible and intangible factors
- Interrelationships among variables are taken care and hence improve the reliability of decision making
- Offers an opportunity to understand the cost and benefit implications of delaying or avoiding a particular decision using sensitivity analysis

Zero One Goal Programming (ZOGP)
- Enables the identification set of BRs and CSFs that should be considered critical for planning
- Offers an opportunity to include more than one conflicting supply chain objective at a time in the model formulation
- Prioritizes goals in a hierarchy of importance and aims to minimize the deviations between the desired goals and the realized results

QFD
- Helps to outline and relate supply chain requirements and business needs
- Helps to understand supply chain planning needs clearly
- Acts as a template to collect and integrate the results of ISM and ANP in one place
- Helps to prioritize supply chain requirements and hence enable decision making based on key or critical SCRs
- Ensures fulfillment of OEM/customer-stipulated requirements and hence can offer an adequate basis to SMEs to negotiate and discuss with supply chain players
ZOGP model to determine a set of supply chain requirements. In a supply chain context, QFD can help organizations in three ways: understanding supply chain requirements clearly and identifying hindrances to lead time and customer service. In addition, QFD enables an organization to allocate resources and coordinate skills and functions based on customer needs. The key HOQ development components are explained in Table 1.

To make ANP results more reliable and hence overall outcomes of the proposed decision methodology better, use of ISM is integrated. ISM is a methodology for identifying and summarizing relationships among specific items that define an issue or problem. It provides a means by which a group can impose order on the complexity of the items (Mandal & Deshmukh, 1994). The various steps involved in ISM are summarized in Figure 2.

ISM helps to establish a "leads to" relationship in a structured and logical manner that can assist the ANP application further. The ANP approach, which allows for modeling interrelationships within HOQ, is employed to determine a representation of business needs. ANP consists of two stages: the first is the construction of the network and the second is a calculation of priorities. In order to construct a structure of the problem in ANP, all interactions among the elements should be considered. When the elements of a component Y depend on another component X, this relation is represented with an arrow from component X to Y. All of these relations are evaluated by pair-wise comparisons and a supermatrix, which is a matrix of influence among the elements. The supermatrix is raised to limiting powers to calculate the overall priorities and thus the cumulative influence of each element on every other element with which it interacts (Saaty, 1996). Steps of the ANP model and its applicability in various areas are well documented (Meade & Sarkis, 1999; Saaty, 1996). A pictorial view depicting an integrated use of ISM and ANP is presented in Figure 3. The successful application of an ISM-ANP-integrated approach is demonstrated by Thakkar et al. (2005, 2007). To invest more time on analysis and maintain accuracy in accommodating the results of one model to another, analysis is carried out using a beta version of ANP software called "Super Decision." This has been accomplished mainly by using functions such as "Design" and "Network" from the toolbar. Other toolbar features "Compare" and "Compute" are used to carry out pair-wise comparisons and priority computation for each stage. Formation of a[J]"Super Decision" matrix and a final synthesis have helped to obtain the final priority scores for various alternatives. These features are available within the toolbar function "Compute." The criteria comparison is made throughout the analysis using Saaty's nine point scale given in Table 2.

The relative importance weights of goals are computed employing pair-wise comparisons. Finally, all the previously calculated data are integrated within a ZOGP formulation to determine the supply chain planning requirements for SMEs. The weighted goal-programming model considers all the goals simultaneously by forming an achievement function that minimizes the total weighted deviation from all the goals stated in the model. This property of ZOGP enables us to incorporate conflicting supply chain objectives such as cost effectiveness versus a responsive supply chain, a network of physical assets versus a network of relationships, and so on. For example, select supply chain conflicts are summarized in Table 3. In formulating a goal-programming model that includes multiple qualitative goals, a method based on pair-wise comparisons such as AHP or ANP appears as an effective means for assessing relative weights (Karsak et al., 2003). The overall ZOGP formulation can be outlined as follows:

$$\text{Minimize: } \sum_{j=1}^{n} \left( d_j^i - d_j^i \right)$$

$$\text{Subject to: } \sum_{i=1}^{m} a_{ij} x_i = b_j$$

where $i=1,2,3,\ldots,n$

$\text{where } j=1,2,3,\ldots,n$

The various phases of the proposed supply chain planning framework for SMEs are presented in Figure 4. Figure 4 is a generalized framework that includes a set of supply chain planning critical success factors (CSFs) and business requirements (BRs). The computations performed in section 3 are only for a set of relevant CSFs and BRs for the organization studied in this research.

### Table 2

<table>
<thead>
<tr>
<th>Intensity of importance</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two activities contribute equally to the objective.</td>
</tr>
<tr>
<td>3</td>
<td>Weak importance of one over another</td>
<td>Experience and judgment slightly favor one activity over another.</td>
</tr>
<tr>
<td>5</td>
<td>Essential or strong importance</td>
<td>Experience and judgment favor one activity over another.</td>
</tr>
<tr>
<td>7</td>
<td>Demonstrated importance</td>
<td>An activity is strongly favored and its dominance is demonstrated in practice.</td>
</tr>
<tr>
<td>9</td>
<td>Absolute importance</td>
<td>The evidence favoring one activity over another is of the highest possible order of affirmation.</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>Intermediate values between two important judgments</td>
<td>This is when compromise is needed.</td>
</tr>
</tbody>
</table>

**Note:** If activity $i$ has one of these non-zero numbers assigned to it when compared with activity $j$, then $j$ has the reciprocal value when compared with $i$.
## Benchmarking CSFs

<table>
<thead>
<tr>
<th>X – US</th>
<th>ORG1, ORG2... - Other organizations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Benchmarking CSFs</td>
</tr>
</tbody>
</table>

### Business requirements (BRs)

<table>
<thead>
<tr>
<th>Importance weights</th>
<th>High product variety</th>
<th>Demand for last minute innovations</th>
<th>Buyers’ expectations for small batch size</th>
<th>Reduction in delivery lead time</th>
<th>Flexibility in consignment receipt</th>
<th>Continuous cost reduction</th>
<th>After sales service</th>
<th>Weighted importance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Supply chain planning CSFs

1. Effective partnerships and information links with trading partners
2. Improved communication
3. Integration of logistics with other functional areas
4. Considering SCM as a business strategy
5. Involvement of suppliers, distribution centers, and customers
6. Correct choice of IT
7. Collaborative buyer-supplier relationships
8. Effective production planning and control
9. Improved trust among supply chain partners
10. Availability of performance measurement tools and matrices
11. Equitable distribution of power in chain

### Overall priority of BRs

#### SC conflict 1

#### SC conflict 2

#### SC conflict 3

### Identifying correlations using ISM

#### Relationship matrix using intermediate ANP results

#### Rating of each BRs with respect to additional goals (SC conflicts) using pair-wise comparison

### ZOGP SOLUTION – IDENTIFYING CRICAL BRs FOR SC PLANNING

Minimize: $\sum_{j=1}^{n} P d_{ij} + d_{ij}^*$, where $j=1, 2, 3, \ldots, n$

Subject to: $\sum_{i=1}^{m} (a_{ij} x_j - d_i - d_i^*) = b_i$, where $i=1, 2, \ldots, m$

### Figure 4

SC planning framework for SMEs
### An Illustrative Application

This section develops an application of the proposed decision framework for the case organization ABC. Company ABC manufactures shot blasting equipment for surface preparation. The present turnover of the organization is 150 million units per annum. Its mission is "to become the largest surface preparation systems provider in Asia known for its quality, technology, fully integrated range of shot blasting equipments, innovation, dynamism, ethical behaviour, and business results, and build long-lasting customer relationships that will make us their preferred supplier." A product portfolio includes equipment such as tumblast (WTB-1.5/3/6), a roller type cabinet (4 W/A-36”), a fully automatic new generation tumblast (TBR-6/TBR-12), a car table cabinet (2-W/A-8” Dia.), and so on. The company had entered into the merger with the industry leader with a focus to improve on technological strengths and global access. The major customer segments of the company include auto industries, foundries, railways, defense, ship builders, and so on. The company offers an annual maintenance contract and aims to expand its spare parts business. The company is also considering expanding its export market, orders from government, growing foundries and forging segments, presence in the auto industry, and so on. The company does not consider its present level of trust and interpersonal relationships with suppliers and customers sufficient to create differentiation and learning advantages in partnerships. However, the motivations behind practicing in a supply chain include improvement in delivery schedules, streamlined procurement, and a finance function. The company considers its service quality and timely delivery of machine spare parts as winning criteria for

<table>
<thead>
<tr>
<th>SC conflict</th>
<th>Significance</th>
<th>Relevance for the case of SMEs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outsourcing versus in-house manufacturing</td>
<td>Critical factors affecting outsourcing dilemma include</td>
<td>The uncertainties associated with outsourcing decisions pose key challenges for SMEs such as</td>
</tr>
<tr>
<td></td>
<td>• Cost versus responsiveness</td>
<td>• Does outsourced function fall into the premise of core activities?</td>
</tr>
<tr>
<td></td>
<td>• Benefit versus risk</td>
<td>• If so, then, what is the possibility of retaining knowledge and learning from such a function</td>
</tr>
<tr>
<td></td>
<td>• Switching costs</td>
<td>once it has been outsourced?</td>
</tr>
<tr>
<td></td>
<td>• Potential loss of efficiency versus strategic flexibility</td>
<td></td>
</tr>
<tr>
<td>Managing supply versus demand specifically when one or a few organizations dominate in the supply chain</td>
<td>Traditional supply chains, with a single dominant player, often result in high costs and poor service because supply and demand are not managed along the chain.</td>
<td>To avoid unnecessary queuing due to increasing capacity utilization rates, SMEs are expected to treat set-up time reduction as a prerequisite for reducing lot sizes.</td>
</tr>
<tr>
<td>Reducing the number of suppliers versus increasing the number of sources of innovations</td>
<td>• Ease in communication</td>
<td>SMEs need to thoroughly evaluate the trade-off between benefits emerging from reducing the</td>
</tr>
<tr>
<td></td>
<td>• Reduced inventory management costs</td>
<td>supplier base and the risk that other sources of innovation are cut off.</td>
</tr>
<tr>
<td></td>
<td>• Increased economies of scale</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Coordinated replenishment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Improved buyer-supplier product design relationship</td>
<td></td>
</tr>
<tr>
<td>Cost effective versus responsive supply chain</td>
<td>• Responsiveness demands smooth and increased flow of information, development of collaborative relationships, and building inventory of critical components.</td>
<td>SMEs need to decide on the strategies that can initially help to improve their effectiveness and then</td>
</tr>
<tr>
<td></td>
<td>• Efficiency demands elimination of nonvalue-added activities, economies of scale, and establishing information linkages.</td>
<td>the desired level of responsiveness needed to meet the requirements stipulated by OEMs.</td>
</tr>
<tr>
<td>Varying buyer-supplier relationships at the upstream and downstream sides of supply chain</td>
<td>Supplier contracts have increasingly become long term and more and more suppliers must provide customers with information regarding their processes, quality performance, and even cost structure.</td>
<td>SMEs face heavy disruption in their planning because of varying demands and expectations of upstream and downstream side players.</td>
</tr>
<tr>
<td>Managing network of physical assets versus network of relationships</td>
<td>Relationship-centered organizations recognize the importance of maintaining strong and enduring ties with key suppliers as markets become more dynamic and demanding.</td>
<td>Selecting what kind of relationship with either customers or suppliers is not determined by the SMEs.</td>
</tr>
<tr>
<td>Normal supply chain versus adaptable supply chain</td>
<td>• Monitor economies all over the world to spot new supply bases and markets.</td>
<td>SMEs need to develop better understanding of market trends and make necessary changes in their business decisions and plans.</td>
</tr>
<tr>
<td></td>
<td>• Use intermediaries to develop fresh suppliers and logistics infrastructure.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Evaluate needs of ultimate consumers, not just immediate customers.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Create flexible product designs.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Determine where companies' products stand in terms of technology cycles and product life cycles.</td>
<td></td>
</tr>
<tr>
<td>Trust, commitment, and values necessary for value chain versus opportunism</td>
<td>• The values practiced by top management carry the greatest impact on supply chain relationships and planning.</td>
<td>SMEs specifically are working in a skeptical environment decided mainly by the set of characteristics of their culture and described by the owner or CEO of the organization.</td>
</tr>
</tbody>
</table>

**Table 3: Key supply chain conflicts and their relevance for SMEs**
establishing good relationships with customers. A quick overview of the company’s previous six months customer complaint record uncovered the following issues:

- Machine failures and delay in services
- Frequent failures of bought-out components such as convener belts and an inability to improve the present suppliers or identify new ones
- Sluggish response to customer queries
- Communication gaps and misunderstanding regarding specifications and requirements of machine spare parts
- Shortages of spare parts
- Interchangeability of parts
- Inability to provide skilled technicians to attend customer complaints

In addition, the company considers the following reasons important to lower the use of IT and e-commerce solutions:
- High cost of developing electronic interfaces
- A lack of awareness of availability and use of technology
- Resistance to change

The purchase manager offers the following reasons behind the

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**Table 5**

Interrelationship among CSFs for case organization ABC

<table>
<thead>
<tr>
<th>Factors</th>
<th>Reachability set</th>
<th>Antecedent set</th>
<th>Intersection set</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>a abhi</td>
<td>abcdej</td>
<td>a</td>
<td>VI</td>
<td></td>
</tr>
<tr>
<td>b bcehfk</td>
<td>bdfj</td>
<td>b</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>c acehik</td>
<td>bcdfcj</td>
<td>c</td>
<td>IV</td>
<td></td>
</tr>
<tr>
<td>d abedghijkl</td>
<td>d</td>
<td>d</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>e aeghfk</td>
<td>bcdel</td>
<td>e</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>f abcdeghi</td>
<td>df</td>
<td>f</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>g ghij</td>
<td>abdefg</td>
<td>g</td>
<td>VII</td>
<td></td>
</tr>
<tr>
<td>h hijk</td>
<td>abcdeghij</td>
<td>h</td>
<td>VIII</td>
<td></td>
</tr>
<tr>
<td>i ik</td>
<td>abcdeghij</td>
<td>i</td>
<td>IX</td>
<td></td>
</tr>
<tr>
<td>j abchjk</td>
<td>ai</td>
<td>j</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>k agjk</td>
<td>bcdeljk</td>
<td>k</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

---

The purchase manager offers the following reasons behind the choice of IT:

- **a. Effective partnerships and information links with trading partners**
- **b. Improved communication**
- **c. Integration of logistics with other functional areas**
- **d. Considering SCM as business strategy**
- **e. Involvement of suppliers, distribution centers, and customers**
- **f. Correct choice of IT**
- **g. Collaborative buyer-supplier relationships**
- **h. Effective production planning and control**
- **i. Improved trust among supply chain partners**
- **j. Availability of performance measurement tools/matrix**
- **k. Equitable distribution of power in chain**

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In addition, the company considers the following reasons important to lower the use of IT and e-commerce solutions:

- High cost of developing electronic interfaces
- A lack of awareness of availability and use of technology
- Resistance to change
disturbed purchasing function:

- Use of a multiple supplier policy to negotiate better and remain on a safer side in case of emergencies.
- Greater importance to criteria such as quality, price, and lead time in evaluating and selecting suppliers. In turn, the company considers assurance to timely payments and long-term business as important offerings to their suppliers.
- Delays in outstanding payments have demotivated potential suppliers from entering into long-term business contracts. This has forced the company to purchase from local-market in cases of emergency even when prices are 10 to 15% higher.
- A new supplier enters into a contract with more legal conditions and higher prices to recover any loss in case of payment delays.
- The unavailability of full truck loads forces the company to purchase material at a higher price when the order is actually in transit.
- The purchasing function suffers in cases of incomplete engineering specifications and work details received from the marketing department.
- The design department doesn’t offer a complete bill of material, which results in duplications of order placing, expediting efforts, and a wasting of resources such as managers’ time, telephone calls, faxes, and so on.
- Sometimes, the company deals with three to four simultaneous projects or products. The material rejected from the kit of one project is compensated from the other by the production department. The company delays the payments to credit-offering suppliers, who then suffer compared to suppliers who only work on cash payment conditions. This damages the company’s image and credibility in the market.

During a one-year period, the senior managers and owners of our case organizations were consulted. Their responses were collected and jotted down using semi-structured interview questions, field notes, and a structured questionnaire, which satisfied the input requirements of an ANP model. The key results of the proposed supply chain planning framework are presented in Figure 5, Figure 6, and Table 4. Figure 5 reports an ISM-based digraph and interrelationships among supply chain planning CSFs; Figure 6 reports ANP-based priorizations. Table 4 determines the relative weightings of BRs for two supply chain conflicts relevant to Company ABC. The priority values are considered as an input in the ZOGP model formulation. Figure 6 reports the results of LINDO software as applied to a ZOGP formulation.

For the purpose of computation, the functions “Design” and “Network” of ANP “Super Decision” software are utilized. All the nodes of the CSF clusters are connected with BR clusters. On the basis of collected subjective judgments, a synthesis is carried out. Toolbar features “Compare” and “Compute” are used to carry out pair-wise comparisons and priority computation for each stage. The results dictate that BR6 (strong inter- and intra-organizational linkages) is the most important requirement (with a weight of 0.253 - normal priority) and BR4...
Subjected to:

**Constraint 1:** It includes the ANP results as a co-efficient of various BR variables \((x_1, x_2, x_3, \ldots, x_6)\). It intends to confirm that whether overall deviations towards the goal of the ANP system result in values 0 or 1 for the possible inclusion or exclusion of the variable.

\[
0.21x_1 + 0.2x_2 + 0.08x_3 + 0.06x_4 + 0.19x_5 + 0.25x_6 + a - b = 1
\]

**Constraint 2:** It includes the priorities of various BRs determined for supply chain conflict 1 as the co-efficient of variables \((x_1, x_2, x_3, \ldots, x_6)\).

\[
0.33x_1 + 0.125x_2 + 0.153x_3 + 0.042x_4 + 0.33x_5 + 0.032x_6 + c - d = 1
\]

**Constraint 3:** It includes the priorities of various BRs determined for supply chain conflict 2 as the co-efficient of variables \((x_1, x_2, x_3, \ldots, x_6)\).

\[
0.123x_1 + 0.028x_2 + 0.164x_3 + 0.366x_4 + 0.077x_5 + 0.168x_6 + e - f = 1
\]

The model is solved using LINDO software yielding the objective function value 0.45574 and selection of business requirements BR1, BR3, BR4, BR5, and BR6 because the values obtained are 1 in each case. The approach has attempted to capture and quantify in a systematic way interdependence and the conflicting nature of supply chain objectives inherent in the supply chain planning process.

**Conclusions and Implementation Issues**

The contribution an ISM-QFD-enabled ANP-GP decision framework adds quantitative precision to an otherwise judgmental decision process in SMEs. The proposed approach is unique in three ways: (1) it models interdependencies among supply chain CSFs in HOQ, (2) it incorporates these interdependencies in ANP and relates them to various business requirements, and (3) it incorporates the multi-objective nature of the problem by allowing the inclusion of various supply chain conflicts along with ANP results as additional goals in the ZOGP model formulation.

It is necessary to note that the proposed approach is not without its own limitations. However, more operational comments can be made only when the developed framework is utilized for some

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**Table 4** Priorities of business requirements for two supply chain conflicts

<table>
<thead>
<tr>
<th>BR1</th>
<th>BR2</th>
<th>BR3</th>
<th>BR4</th>
<th>BR5</th>
<th>BR6</th>
<th>Priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/5</td>
<td>1/3</td>
<td>1/5</td>
<td>1/5</td>
<td>2</td>
<td>1/2</td>
<td>0.090</td>
</tr>
</tbody>
</table>

Table 4 describes the priorities of business requirements for two supply chain conflicts - “outsourcing versus in-house manufacturing” and “varying buyer-supplier relationships” using initial and normalized matrices. The table provides a systematic way to prioritize business requirements based on their importance and contribution to overall supply chain planning.

(satisfactory installation and after-sales service) receives the least weight (0.0622).

Based on the weight determined in these results (Figure 6 and Table 4), a ZOGP model is constructed. The overall objective of this model is to examine the deviations to an overall ANP objective (to improve supply chain planning in this case) and supply chain conflicts (for case organization A, two supply chain conflicts - outsourcing versus in-house manufacturing and varying buyer-supplier relationships - are found critical). Here, business requirements (BRs) are taken as \(x_1, x_2, x_3, \ldots, x_6\) and deviations (positive and negative) are taken as \(a\) and \(b\) (upper and lower deviations) for constraint 1 (ANP related), \(c\) and \(d\) (upper and lower deviations) for constraint 2 (conflict 1 - outsourcing versus in-house manufacturing), and \(e\) and \(f\) (upper and lower deviation) for constraint 3 (conflict 2 - varying buyer-supplier relationships). The ZOGP formulation for the set of business requirements and supply chain conflicts is as follows:

**MIN** \(0.608a + 0.264c + 0.128e\)
duration of time. The key precautions are outlined as follows so that case organizations can perform an effective application of the proposed approach:

1. SMEs should analyze market trends, customer preferences, competitor’s practices, and internal dynamics of an organization before implementing this framework.

2. The proposed conceptualization requires a number of subjective judgments. The behavioral accuracy of the model further depends on the care taken in their collection. Techniques such as group discussions; nominal group technique (NGT); strength, weakness, opportunity, and threat (SWOT); and political, environmental, social and technological (PEST) analysis; and so on can be utilized in an open and interactive environment.

3. It is necessary to caution analysts about finding a desired arrangement of variables in a proper template. Different software provides various kinds of templates for clustering the variables; an appropriate selection is necessary to generate the right kind of pairwise comparisons made available in the beta version of “Super Decision” (ANP) software. This will assist the software in generating a series of questions in an appropriate manner for the collection of subjective judgments. Thorough analysis of the situation at an early stage improves the consistency index in the ANP model.

The complexity involved in the implementation of the proposed framework can be described in terms of four factors: strategy, leadership, culture, and capability. Each of these elements is connected in two ways (as conceptualized in Figure 7) with each other and simultaneously exercises the influence on implementation of the suggested frameworks. A set of arguments are offered to justify the importance of these factors in the implementation of developed frameworks in the context of SMEs:

- **SMEs** are governed by the strategy formulated by their owners or CEOs and hence it is necessary to match the expectations of the leader with needs of strategy formulation for the successful implementation of frameworks.

- **SME strategy implementation** fails in the absence of needed capabilities and long-term vision for the development of technological or human resource capabilities, which hampers the effective use of frameworks.

- **SMEs** must have a match between culture and capability with a highly lucid and flexible work culture to take the fullest advantage of the money and time invested in its development.

- **The link between culture and leadership in SMEs** is critical in the way that the expectations and vision of the owner or CEO dictate the practices and kind of value system to be adopted by people.

- **Strategy**: Strategic small firms are likely to have the significant capability to grow, expand, innovate and introduce new products to the marketplace and to achieve greater profitability (Vaaland & Heide, 2007; Huin et al., 2002). This calls for an acceptance of frameworks at a strategic level.

- **Leadership**: Leadership is defined as “the process of transforming organizations from what they are to what the leader would have them become” (Dess & Lumpkin, 2003, p. 4). It is a vital ingredient in the formulation and deployment of strategic plans and in the achievement of strategic competitiveness and above-average returns.

- **Culture**: Strategy and culture are inseparable and firms that can, retain and enhance their competitiveness by incorporating a sharing culture into the overall strategic direction of the firm. It is necessary for SME managers to bring to the surface and challenge their old assumptions to become receptive to the requirements of changing competition.

- **Capability**: It is necessary for SME businesses to strive for a set of capabilities such as involvement of top management, involvement of line managers, flexibility to adapt to unanticipated changes, commitment to advertise and promote the product or service, and the ability to make rapid design changes to receive the maximum advantage of proposed frameworks.

![Figure 7: Implementation polygon](image-url)
References


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