# A Composite Process for Establishing and Continuously Maintaining End-to-End Visibility in Multi-Tier Supplier Network Systems

**Joel Jolayemi**[*], **Festus Olorunniwo, Chunxing Fan and Xiaoming Li**
*Department of Business Administration, Tennessee State University, Nashville TN USA*

## Abstract

*We develop a composite process for establishing and continuously maintaining end-to-end visibility in multiple multi-tier supplier network systems. The composite process is made up of: (1) the dig-down and shovel-up procedure for mapping and developing critical supplier network paths, (2) the dig-down and shovel-up procedure for establishing the visibility of tier suppliers in all critical supplier network paths, and (3) the dig-down and shovel-up procedure for using scorecard for evaluating every critical tier supplier in multi-tier supplier network systems. The steps to be followed in applying each of these procedures are developed and presented together with an illustrative flow chart. A list of information items that can be collected, transmitted, shared, and stored during the applications of the composite process is also developed. We also develop a list of follow-up actions and decisions that can be taken after establishing the visibility of tier suppliers and after each scorecard evaluation cycle. Furthermore, an outline of the procedure by which decision support system can be used for effectively and efficiently sharing, transmitting, storing, and accessing information during the applications of each of the procedures of our composite process is developed. Additionally, we do a critical review of the current approaches used in some industries for engendering tier supplier visibility. To the best of our knowledge, the composite process and its constituent procedures are the first and best of their types as tools for engendering tier supplier visibility. They are devoid of all the shortcomings of the current industry approaches.*

*Keywords: Critical supplier network path, critical tier suppliers, dig-down-and-shovel-up procedure, industry's approaches, scorecard, supplier relationship management.*

## 1. Introduction

Traditionally, the focus of supplier relationship management (SRM) in organizations does not go beyond an organization's first-tier suppliers. This has been its major inadequacy, its many documented benefits and values (witness

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[*] Corresponding author. Email: jjolayemi@tnstate.edu

Atkinson, 2009; Avery, 2007; Day, 2008; Genna, 1997; Gordon, 2008; Hughes, 2007; Kearney, 2004; Kraljic, 1983; Pickett, 2006; and Wong, 2000; to mention a few) notwithstanding.

In this era of globalization, an organization's suppliers may be located in different parts of a country or the world. Each of these suppliers may also have suppliers that are similarly located. Continuing in this way, this relationship trend can lead to complex networks of upstream (upstream to the organization) multiple multi-tier suppliers whose lowest tier levels can go down as far as tier-10 or more. These complex networks of multi-tier suppliers have to be well and efficiently managed in order to maximize customer-supplier relationship value and minimize costs and risks across the multiple multi-tier supplier network (MMTSN) systems. Some of the tier suppliers in the MMTSN system may be critical business links. So critical that if any one of them has any critical operational and/or management problem or is affected by any major incident or disaster, the adverse effects on the organization or original equipment manufacturer (OEM) can be very serious. This situation creates a dire need for the developments of methodologies and models for establishing and maintaining multi-tier supplier visibility and for integrating and synchronizing SRM activities, strategies, information sharing, planning, operations, and risk management across MMTSN systems.

Multi-tier supplier visibility encompasses the ability to - on continuous basis - know and understand the environmental situations, the financial health, the capabilities, the operational performance, the practices, and the strategic and operational activities of all tier suppliers who are the OEM's critical business links. According to Beck (2011), it is ultimately about connecting distributed supply chains across multiple partners and geographies. It also relates to gathering up-to-the-minute data from tier-1, tier-2, all the way to tier-n suppliers, distributors, and logistics providers (see Beck, 2011).

Many experts, professionals and SC consulting companies like Beck (2010), Briscoe et al. (2004), Clark et al. (2009),  Jolayemi et al. (2009), Christopher and Lee (2004), KinaXis (2013), and White and Mohdzain (2005), just to mention a few,  that have been advocating the development of a procedure or model like this have articulated its many potential and great benefits.

Beck (2011) averred that multi-tier visibility and collaboration facilitates for more seamless product launches, ongoing streamlined operations, reduced planning cycle, improved supplier performance, and less supply chain risk. Briscoe et al. (2004) pointed out that quality could improve if the OEMs would know about the capabilities of their lower-tiers.

According to Clark et al. (2009), multi-tier visibility and collaboration has the effect that problems arising at any tier level of the supply chain can be recognized and ameliorated by the OEM, either by the OEM taking direct action or instructing its suppliers downstream to take certain actions.

Jolayemi et al. (2009) stated that the benefits or advantages of having lower-tier supplier visibility and of integrating and optimizing the strategies and

operations of suppliers with those of the OEM are enormous and that the disadvantages of not doing so can be ruinous. Christopher and Lee (2004) opined that "end-to-end" visibility is one of the key components to enhance supply chain (SC) confidence and minimize risks. KinaXis (2013) holds the view that visibility is a critical step to sense and shape demand. In their own article, White and Mohdzain (2005) observed that the major benefit of the multi-tier information system was the moving from a reactive management of the supply chain to a proactive one.

A company that is known to have made some good efforts to have the visibility of some of its tier-supplier networks and derived good benefits from them is Toyota. By establishing and maintaining the visibility of some of its multi-tier suppliers up to tier-3, the company has been able to develop new cars with shorter development cycle times and lower development costs (see Tang, 1999 and Tang and Zimmerman, 2009).

The problems experienced by Boeing during the development of its 787 Dreamliner also reinforce the need for engendering multi-tier supplier visibility. Boeing announced a delay in the first flight of its Dreamliner in September 2007, citing some ongoing changes including parts shortages and remaining software and systems integration activities. (Also see Tang and Zimmerman, 2007). The main problems that lead to these changes are problems relating to the coordination of supplier (tier-supplier) development activities and of getting accurate and timely information from tier-suppliers. According to Tang and Zimmerman (2009), one of the tier-1 suppliers, Vought, hired Advanced Integration Technology (AIT) as a tier-2 supplier to serve as a system integrator without informing Boeing. AIT is supposed to coordinate other tier-2 and tier-3 suppliers for Vought (Tang, 2007). However, some tier-2 or tier-3 suppliers did not often enter accurate and timely information into the Boeing's Exostar system used for coordinating supplier development activities. As a result, various tier-1 suppliers and Boeing were not aware of the delay problems in a timely fashion, which makes it difficult for Boeing to respond to the problems quickly (Tang and Zimmerman, 2009).

While there is abundant theoretical and empirical literature in other areas of supply chain management (SCM) (see Jolayemi and Fan, 2012; Daugherty, 2011; and Schoenherr et al., 2012), there is a dearth of literature on the development of procedures, methods, or models for engendering multi-tier supplier visibility. To the best of our knowledge, Clark et al. (2005) are the only scholars that have done any serious work in this area. Even then, they did not publish their work in full. Therefore, it is safe to say that we have yet to come across any single publication that reports the development and/or application of any elaborate, well-planned, or well-developed methodology, process or structure for managing lower-tier suppliers or for engendering their visibility and integrating and synchronizing their strategies, supplier relationship/development

activities, operational plans and risk management strategies and activities end-to-end across multiple supplier-tier levels.

It must be mentioned, though, that there have been numerous small articles in trade magazines and on the internet on multi-tier supply chain visibilities. These articles have been mostly focused on discussions about advantages of engendering SC or multi-tier supplier visibility and the risks of not doing so. (See Atkinson, 2009; Avery, 2007; Becks, 2010; Hughes, 2004; KinaXis, 2013; and Leach, 2011 for a few examples). None of the articles suggests or presents any method or procedure for actual engenderment of multi-tier visibility.

In the industrial world, the Boeing Company (Gordon, 2008); the General Motors (GM) (Hannon, 2006); Apple, Dell, Motorola, and Avon (Becks, 2010); and Toyota (Tang, 1999) are the only organizations known to be making some efforts towards developing some processes for engendering visibilities of their own tier suppliers. Relatively, Boeing and Toyota appear to be making more conscientious and more serious efforts than other companies but the two companies have not gone beyond the third tier of their MMTSN system (witness Gordon, 2008). However, none of the two organizations has made its process or method available in any public domain. In fact, as it will be seen later in this paper, our earlier investigation (see Jolayemi et. al., 2009) of general industry practices could not find any serious process for engendering lower-tier supplier visibility out there in industries.

White and Mohdzain (2005) reported an OEM that, on receiving customer demand, passes demand signal to a tier-1 supplier. He reported further that, in turns, the tier-1 supply, who is a producer of highly engineered metal components, passes on the signal to a tier-2 supplier of specialist materials. It must be noted here that the focus of this two-tier relationship is mainly to pass demand information from the OEM to tier-1 and tier-2 suppliers but not on complete multi-tier visibility.

In our research, we will develop a composite process (CP) for establishing and maintaining end-to-end visibility in MMTSN systems. The process will consist of a set of three procedures that have to be developed in a sequential order. The steps of each procedure and the flow chart illustrating the steps will be presented. We will suggest the ways by which technology can be applied to make the CP very efficient and effective. Information that can be collected, stored, and shared by the OEM and tier-suppliers for the continuing maintenance of visibility of the critical suppliers in the MMTSN system will be highlighted. Follow-up actions that can be taken to address issues that are identified each time the CP or any of its constituent procedure is applied will be highlighted.

One of the major reasons for the importance of multi-tier supplier visibility is that an OEM must first establish the visibilities of its tier suppliers before it can ever embark on the integration of its supply chains or on collaborative relationships across its supply chains. Additionally, multi-tier supplier visibility has to be maintained after been established for supply chain integration and/or collaboration to succeed. Therefore, our CP will be an important bedrock for the

success of any effort to be made in establishing collaboration or integration of any SC.

A study of the approaches used by some companies to maintain the visibility of their lower-tier suppliers was undertaken and reported by Jolayemi et. al.(2009). We will do a critical review of these approaches before developing our CP.

The paper is organized as follows. Section 1 presents the introduction, the literature review, the objectives, and the organization of our paper. Section two presents a critical review of some approaches reported by Jolayemi et al. (2009) from their industry survey on the approaches used by some companies to maintain the visibility of their lower-tier suppliers. Section 3 is devoted to the developments of our CP. This section also suggests how the procedures can be efficiently and effectively applied in organizations. Summaries, concluding remarks, and recommendations for future research are presented in section 4.

## 2. Critical Reviews Of the Current Industry and Literature Methods/Approaches

Jolayemi et al. (2009) investigated the methods/procedures used by some companies to engender the visibility of tier suppliers in their multi-tier supplier networks. They conducted telephone interviews with the supplier executives of these companies. One of the major focus of their interview relates to the processes or procedures that some companies use to gain and maintain multi-tier visibility. They discovered that many companies do not have the visibility of their tier suppliers and that multi-tier supplier visibility does not go beyond tier-2 level for the few companies that do.

They reported the following as the methods/procedures used by the few companies that maintain some multi-tier visibility.

a) Deep-down multi-tier probing and intra supplier collaboration.
b) Dual function approach.
c) Empowerment with tightened control.
d) Lower-tier supplier certification.
e) Market Supplier Intelligence.
f) Multiple-function oversight approach.
g) Strict contract with lower-tier supplier.

We will next present a critical review of each of these methods/procedures. A major reason for doing this is to let our readers have a good understanding of these industry methods and of their strengths, shortcomings, and limitations and to better understand and appreciate the need for

better methods. Another major reason is for our readers to understand the big gaps that will be filled by our CP.

## 2.1. Deep-Down Multi-tier Probing and Intra supplier Collaboration

This is an approach whereby the OEM develops questionnaires that is given to its first tiers to fill with an expectation that the first tiers would do the same to its first tiers and so forth so that it can gain knowledge of its lower tiers. The OEM further requires the lower tiers to align their goals with the OEM.

The good thing about this approach is that if well managed, it can enable the OEM to maintain visibility down to the lowest level of the multi-tier supplier network. However, the procedure has some shortcomings, namely:

i.     There is no systematic way of operating the procedure to ensure that the lower tier suppliers get the questionnaires, fill it, and pass unfilled copies to their first tiers for them to complete.

ii.    There is no systematic way of getting the completed questionnaires of the information collected with it from any tier supplier back to the OEM.

iii.   The procedure does not have a way of identifying or specifying the category or tier suppliers whose visibilities are required and who should complete the questionnaires.

iv.    The OEM should not just develop questionnaires and send it to its lower tiers to collect information on them. He needs to get buy-in from the lower tiers or, at least, its first tier suppliers and allow them to have input in developing the questionnaire. There are information that some tier suppliers may not like to release if they are not carried along or know how the information are going to be used. This alone can make some tier suppliers to be unwilling to complete the questionnaires.

v.     This approach is not enough for the OEM to identify its critical tier suppliers and to continue to monitor them and their performances regularly using scorecard metrics.

## 2.2. Dual Function Approach

This is an approach in which the OEM buys raw materials or key components from tier -2 or tier-3 supplier in a "flash (virtual) transaction" at a low discount price and sells them to their tier-1 suppliers without taking physical ownership of the goods.

The benefit of this approach is that it enables the OEM to have some sort of direct business relationship with its tier- 2 and/tier-3 supplier(s) and to be able to know them and probably know their capabilities. Nonetheless, the approach has the following shortcomings:

    i.    It places the management of tier- 1 supplier's own first-tier and/or second-tier suppliers under the management of the OEM.  This is an unusual practice. Direct communication and, at least, some sort of collaboration are needed between tier -1 supplier and its own supplier that supplies the raw materials and components it needs to produce its products. It needs to be able to monitor the performances of its own suppliers, share information with them directly and, if needs be, have collaborative plans with them.

   ii.    It may not enable both the OEM and the tier-1 supplier have good information and knowledge of the tier-2 and/or tier-3 suppliers problems as the OEM buys raw materials from them in a virtual transaction and the tier 1 supplier does not have any business relationship with them. Both the OEM and the tier 1 supplier may not be able to monitor the performances of the tier 2 and 3 suppliers. Under this approach, collaborative relationship among the OEM and tier 1 supplier on the one hand and the tier 2 and 3 suppliers on the other hand may not be possible.

  iii.    Apparently, the only major criterion on which the OEM bases the selection of tier-2 and tier-3 suppliers is price. This, in itself, is very wrong. There are many other important attributes or metrics that have to be used together with price in evaluating and selecting suppliers.

  iv.    This procedure may rob the OEM of getting the service of some good suppliers. Not many good suppliers will like to relinquish the management of the suppliers that supply them with the critical materials or components needed for the production of their products to any OEM. Every organization has its own sourcing rules, policy and procedure.  Some organizations may not like to compromise these.

   v.    The procedure creates role confusion.  Who is the real first-tier supplier and who is the real OEM? Is the OEM who buys materials from the tier-2 supplier and sells it to the tier-1 supplier the real first-tier supplier to the tier-1 supplier? Or is the tier-1 supplier who buys the material purchased by the OEM from the tier-2 supplier and uses it to produce the components/parts or products it sells to the OEM the real tier-1 supplier or the real OEM? With this role confusion, how can they relate and manage each other effectively?

  vi.    The procedure may not create real multi-tier visibility for the OEM beyond first tier suppliers as the procedure does not provide ample opportunity to monitor tier-2 and tier-3 suppliers.

### 2.3. Empowerment with Tight Control

In this approach, the OEM scans through the supply base and identifies a tier-2 supplier that produces products and components that are very important, technically complex, and difficult to manufacture and develop contracts and direct relationship with them. The OEM then signs authorization for the tier-1 suppliers to act as their agents and purchase the products and components from the tier-2 suppliers.

The merit of this approach is that it enables the OEM to identify and establish contacts and relationships with the tier-2 suppliers that produce materials, parts, and components that are critical to the products it produces. Another benefit of this approach was articulated by the company that uses it as follows: "We authorize the 1st tier to purchase, so we actually have already secured the price from the second tier and we know how much it is going to cost to deliver to the 1st tier."

The approach has the following drawbacks:

   i.   The procedure may not enable the OEM to have multi-tier visibilities beyond tier 2 suppliers.
  ii.   Not many organizations will find it comfortable to do business under another organizations signed contract rules. In a case of bridge of contract, who is responsible and who holds the other party responsible?
 iii.   Most significantly, the same drawbacks stated in (i) to (iv) in section 2.1.2 for the Dual Function Approach apply to this approach.

### 2.4. Lower-Tier Supplier Certification

This is an approach where the tier-1 suppliers have to select their suppliers from an approved certified vendor list provided by the OEM. If an item cannot be sourced from an approved vendor list, a special evaluation process has to be done under the supervision of the OEM to select a vendor.

The benefit of this approach is that it enables the OEM to have good visibilities of some of its tier-2 suppliers. Another benefit is that the approach puts the OEM in-charge of its tier-1 and tier-2 suppliers.

Like other procedures discussed above, this procedure also has its own shortcomings. The shortcomings are as follows.

   i.   It is not proper for the OEM to disallow its first-tier suppliers from selecting and managing its own suppliers in accordance with its own rules and criteria. Every company has its own sourcing rules and criteria.

ii.   Putting the OEM in-charge of both tier-1 and tier-2 suppliers is not something that many tier-1 suppliers will tolerate. Who signs contract with the tier-2 supplier? Is it the OEM or the tier-1 supplier? Whoever signs contract with the tier-2 supplier should be in charge of it (tier-2 supplier). It will be out of place for the OEM to sign contract with the tier-2 supplier. If that happens, then the tier-2 supplier becomes a tier-1 supplier to the OEM, not a tier-2 supplier.

iii.  This approach can create more problems for the OEM in a global supply chain environment where both the tier-1 and tier-2 suppliers are located in the same country and the OEM in a different country. It will be much easier and more effective for the tier-1 supplier to take charge of the second tier suppliers while the OEM takes charge of the first tier supplier than for the OEM to take charge of the two. The tier-1 supplier will have a better knowledge of the environment and the environmental conditions and culture they (tier-1 and tier-2 suppliers) both operate than the OEM has. What the OEM needs is the visibility of the tier-2 supplier, not to be in charge of it.

iv.   This procedure does not take multi-tier visibility beyond tier 2 suppliers.

v.    An important question in this procedure is: who is in charge of score-carding the tier-2 suppliers? Taking charge means the OEM may do this. Since the tier-1-supplier is the direct customer to the tier-2 supplier and performs business transactions with it on regular basis, it is in a much better position than the OEM to evaluate and monitor the performances of the tier-2 supplier.

## 2.5. Market Supplier Intelligence

This is an approach in which the OEM conducts a complete market supplier intelligence analysis to understand what the supplier's supply chain is and also to understand and find out some key components that may be of concern. Once the key components are identified the OEM would ask the supplier to address the concerns that it (the OEM) may see as important to the success of its company and relationship.

A good benefit of this approach is that it enables the OEM to identify where bottlenecks or critical problems may occur and to alert the concerned supplier and ensure that it (the concerned supplier) takes quick action to solve the problem. Another good benefit is that the intelligence gathered under this approach enables the OEM to maintain information about its suppliers' suppliers.

There are some drawbacks in this approach. These drawbacks are as highlighted below.

i.   This approach could be difficult to operationalize.  It may be too costly and time-consuming for the OEM to conduct a complete market supplier intelligence analysis of its suppliers' supply chain.
ii.  The procedure does not indicate whether or not tier suppliers in the supply chain are carefully selected for the analysis on the basis of their critically.
iii. This approach does not provide for the OEM and its tier suppliers to be all involved in continuously maintaining the visibilities of their lower-tiers. It leaves the OEM to do this alone. How often can the OEM do the analysis in order to ensure that continuous visibility is maintained? The time, effort, and cost involved in the analysis may not make it possible for the OEM to do the analysis regularly enough.
iv.  Some tier suppliers may not be comfortable with the OEM conducting complete market supplier intelligence analysis of their tier suppliers.
v.   The approach does not indicate whether or not the OEM gets buy-in from its tier suppliers on this.

## 2.6. Multiple-Function Oversight Approach

In this approach, more than one corporate function may monitor or manage different tiers (tiers 1 and 2) with lower tiers being evaluated multiple times with different metrics.  For example, a company's supply chain group (on the material side) may be managing tier-1 suppliers while its capital group may be managing tier-2 suppliers whom it may consider its tier-1 suppliers.

The benefit of this approach lies in the fact that it enables a company to have a good visibility of its critical tiers 1 and 2 suppliers and to continuously monitor them. However, the approach has some inadequacies and these are highlighted as follows:

i.   The management of the two different tiers of suppliers by two different functions of an organization may make the management and coordination of supplier relationship management difficult and less efficient and effective. Sharing of information on supplier activities and performance between the two functions could be a problem.
ii.  Whoever manages a tier-2 supplier must be closely associated with its customer (the tier-1 supplier to which it supplies products and materials) and share with it information about the situations and performances (including scorecard performance) of the tier-2 supplier on continuous basis. This approach does not allow that.
iii. The approach cannot enable the OEM to have the visibilities of its tier suppliers beyond tier 2.
iv.  The drawbacks stated in (i) and (iv) in section 2.2 for the Dual Function Approach also apply to this approach.

## 2.7. *Strict Contract with Lower-Tier Supplier*

This is an approach in which the supplier is required by the OEM to manage its lower tiers suppliers provide their regular performance report to it (the OEM) so that it can monitor the key issues. This obligation is directly stipulated in the contract that the first tier supplier has with the OEM.

A benefit of this approach is that it makes a supplier to be responsible for managing and ensuring the visibilities of its own tier suppliers. Another benefit is that it enables the OEM to maintain lower-tier supplier visibility.

Nevertheless, the approach has its own inadequacies. The following are brief highlights of the inadequacies.

i. The OEM should not just be waiting for its suppliers to provide regular performance reports of its lower tiers, it should support the suppliers and work with them to put good processes and procedure in place to ensure that things are done right and done efficiently well.

ii. Stipulating the approach in the contract does not mean that a supplier will do it as specified and produce any good from it. It is only through the leadership and direct involvement of the OEM that good results can be guaranteed.

iii. The OEM should play some roles in identifying its own critical tier suppliers to be monitored. This approach does not allow that.

iv. The accuracy of the information provided to the OEM by the OEM's tier-1 suppliers cannot be guaranteed under this approach due to the total lack of involvement of the OEM in the process.

## 3. The Development of a Composite Process for Engendering End-To-End Visibility in MMTSN Systems

By its nature, a MMTSN system (see Figure 1) is a very complex system with many inherent and complex problems. Some of these problems (and very important ones for that matter) are:

i. The lack lower-tier supplier visibility: the invisibility of the lower-tier supplier risks to the OEM makes it impossible for it to manage or mitigate risks

ii. The lack of any direct or indirect link/connection between the OEM and the lower-tier suppliers, which has made it impossible for the OEM to monitor their performances, and

iii.   The lack of a system/process of establishing links or communication among the suppliers in the MMTSN system, which has hindered the ability of tier suppliers to share critical information among themselves.

Here in this section, we will develop a CP for establishing and continuously maintaining lower-tier supplier visibility in MMTSN systems. We call the process a CP because it is constituted by a set of three separate procedures christened the "dig-down and shovel-up procedures". Each of these three procedures represents a major step or portion of the CP. The three constituent dig-down and shovel-up procedures (DD-and-SU) are:

- The DD-and-SU procedure for mapping and developing critical supplier network (CSN) paths in MMTSN supplier systems.
- The DD-and-SU procedure for establishing the visibility for tier suppliers in all CSN paths.
- The DD-and-SU procedure of using scorecard for evaluating every critical tier supplier in MMTSN systems.

Collectively, these procedures will address the complex problems – particularly visibility problems – associated with MMTSN systems.

We next present steps of each of these procedures and illustrate them graphically.

### 3.1. The DD-and-SU Procedure for Mapping and Developing CSN Paths in MMTSN Systems

The first step in establishing lower-tier visibility in a MMTSN system is to develop CSN paths end-to-end through the system. The level of importance of each tier supplier to its immediate customer has to be considered before it is included or excluded in a critical tier supplier path.

We have developed the DD-and-SU procedure for doing this. An OEM that wants to develop CSN paths in its MMTSN system using this procedure must first discuss the reasons for wanting to do it with its critical tier-1 suppliers and get a buy-in from them before going ahead with it. After the buy-in, the OEM should then ask them to get a buy-in from their own tier-1 suppliers the same way. The discussions and buy-in process should continue upstream until every critical tier-(n-1) suppliers at the (n-1)th tier level gets buy-in from its critical tier-n suppliers, where n denotes the lowest tier-level of any CSN path in the MMTSN. It must be noted that, at this stage, the OEM may not have had any prior information or knowledge of its critical tier-1 suppliers' critical tier suppliers. Similarly, its critical tier-1 suppliers may not have had any prior knowledge or information about their tier-1 suppliers' (the OEM's tier-2 suppliers') critical tier suppliers.
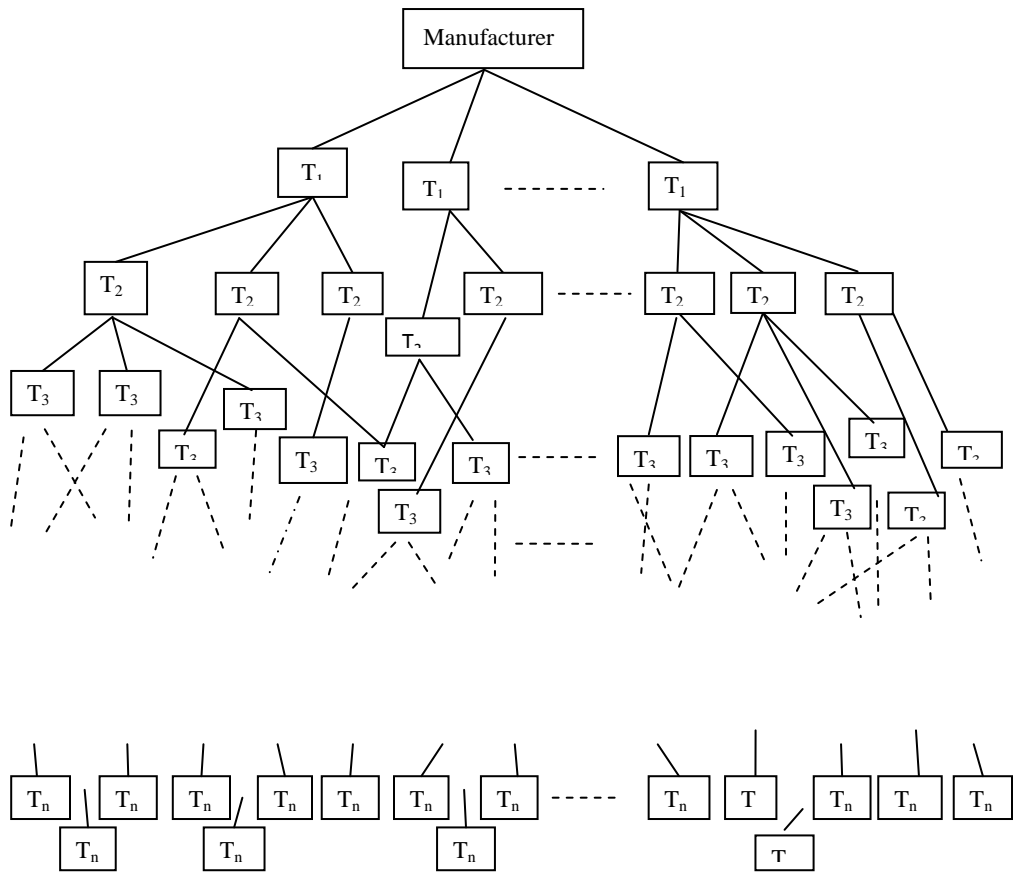
**Figure 1**. A multiple multi-tier supply network

The steps of the procedure and the graphical illustrations of the steps (see Figure 2) are as follows:

**Step 1:** Identify and compile the lists of your tier-1 suppliers.

**Step 2:** Each of the critical tier-1 suppliers compiles the list of its own critical tier-1 suppliers, if there is any, and passes the list to the OEM along with the name and location of each of them and the reasons why each is critical. The suppliers in all the lists passed to the OEM by all the OEM's critical tier-1 suppliers become critical tier-2 suppliers to the OEM.

**Step 3:** Each of the critical tier-2 suppliers compiles the list of its critical tier-1 suppliers (which will become critical tier-3 suppliers to the OEM), if there is any, and passes it to its own customer (its immediate upper tier-2 supplier) along with their names and locations and the reasons why each of

them is a critical tier supplier. The OEM's critical tier-1 supplier then passes the list and the accompany information to the OEM. On reaching the OEM, the critical tier suppliers in all the lists that emanate from all the OME's tier-2 suppliers become the critical tier-3 supplier to the OEM.

**Step 4:** This process continues until each of the OEM's critical tier-(n-1) suppliers compiles the list of its own critical first-tier suppliers (who are at the nth tier or the lowest level of the  CSN paths in the MMSN), if there is any, and passes their names and locations to its own customer (who is also the OEM's critical tier-(n-2) supplier along with the reasons why each of them is a critical tier-n supplier.

Each of the critical tier-(n-2) suppliers passes all the lists received to its own immediate customer or the tier-(n-3) critical tier suppliers to which they supply products or raw materials. The process continues until all the list of all critical tier-n suppliers and their names and locations and the reasons why they are critical tier suppliers finally get to the OEM through its critical tier-1 suppliers.

**Step 5:** The OEM compiles and studies the lists together with the information accompanying them to identify the tier suppliers that are critical to its (the OEM's) supply needs in the MMTSN system.

**Step 6:** Having identified the tier suppliers that are critical to its own supply needs, the OEM then draws the various network paths connecting all its critical tier suppliers from tier-1down to the tier-n level of the MMTSN system.

The diagram in Figure 3 shows an example of a MMTSN system with CSN paths running through it, right from the OEM to the tier-n level. The focus of the OEM will be on the suppliers in the CSN paths in its supplier development activities, risk management strategies, supplier relationship management programmes, planning and implementation of SC collaboration/integration.

Whenever a new supplier is admitted to a CSN path or replaces a supplier in the path, the immediate higher tier supplier or the tier supplier that admits the supplier to the path sends its name, location, and the reasons why it is a critical supplier through to the OEM by following the procedure described above. This is the way each critical network path will always be upgraded.

As can be seen in the rest of this section, the critical tier supplier network paths developed here lays the foundation for the development of each of the remaining DD-and-SU Procedures.
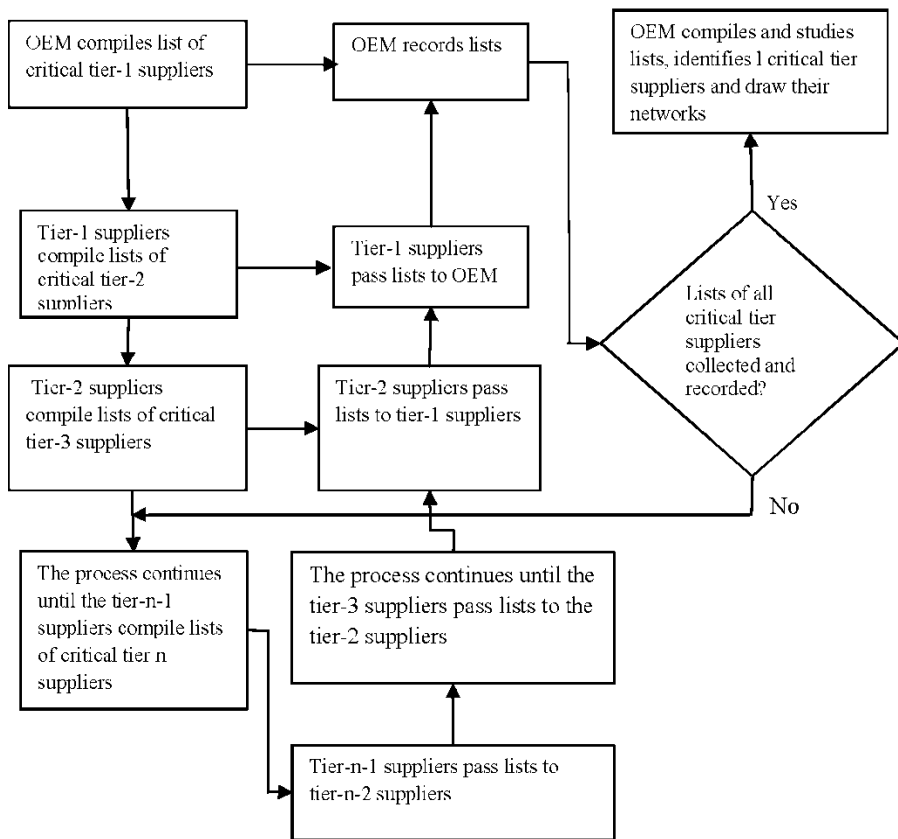
**Figure 2.** The flow-chart for the process of developing critical supplier networks in MMTSN systems

## 3.2. The DD-and-SU Procedure for Establishing the Visibility of Critical Tier Suppliers in MMTSN Systems

After identifying the CSN paths in the MMTSN system (see Figure 3) using the procedure in 3.1, the OEM can now collect all relevant information that can make all the tier suppliers in all the CSN paths visible to it. The OEM may be interested in collecting more comprehensive information about the profile of every critical tier supplier. For example, it may want to collect information about each critical tier supplier's product profile, location, operational and financial performance, most recent scorecard performance, among others.

Before embarking on the information collection process, the OEM must follow the same approach explained in section 3.1 to obtain a buy-in from every critical tier supplier.
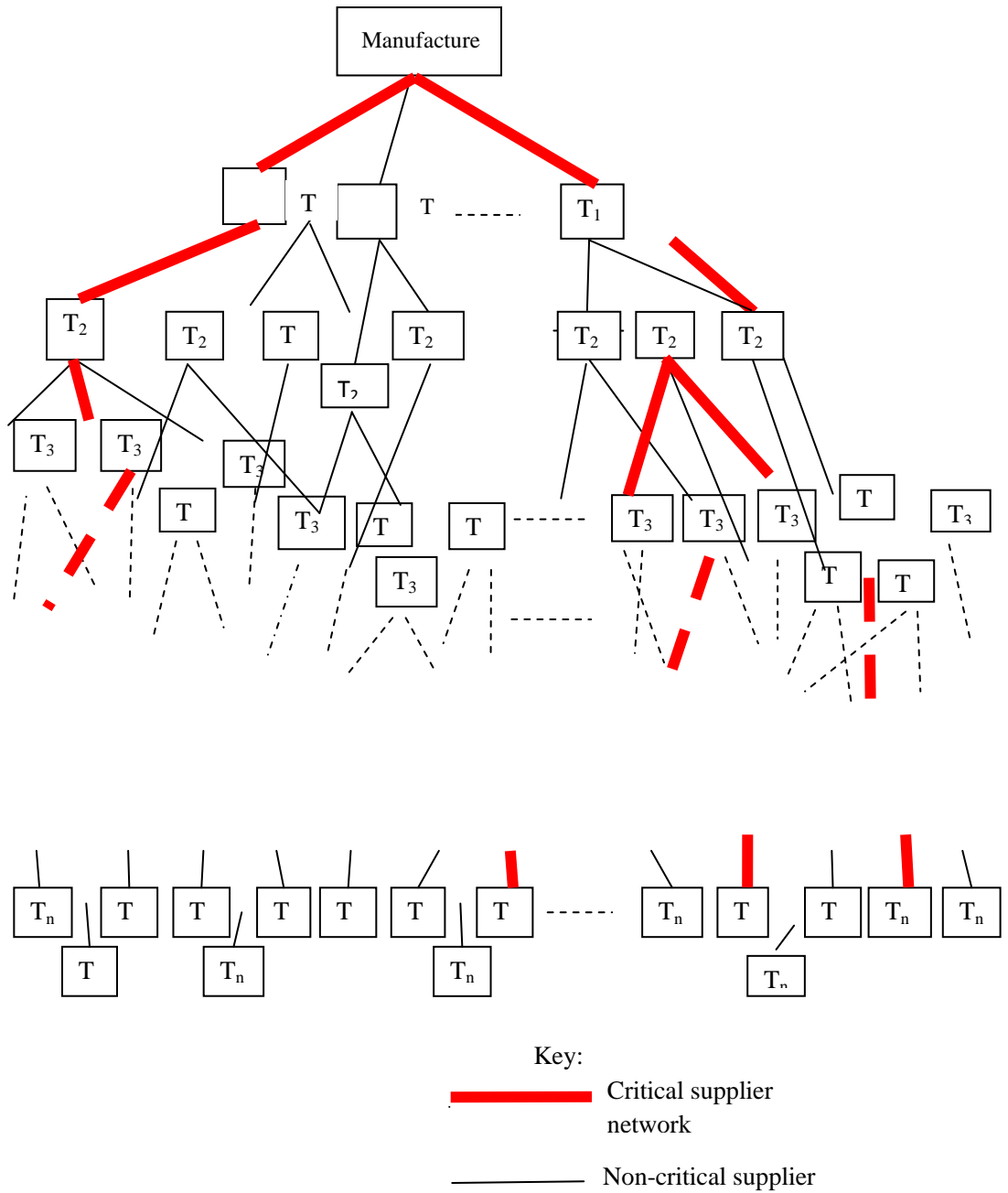
**Figure 3.** A MMTSN system

The steps of the procedure and its graphical illustrations (see figure 4) are as given below.

**Step 1:** Develop a questionnaire for collecting detailed and relevant information about each tier supplier. The information should be detailed enough to allow the OEM have a good visibility of any tier supplier.

**Step 2:** Make the tier-1 supplier on each CSN path the head of its path. Every other tier supplier is also the head of the chain of tier suppliers downstream to it on its CSN path.

**Step 3:** Choose a CSN path.

**Step 4:** Make the Lower-tier- Supplier-Visibility questionnaire available to the tier-1 supplier on the CSN path. The tier-1 supplier uses the questionnaire to collect all needed information on the tier-2 supplier that is directly under it (i.e. its own critical tier-1 supplier) in the path. The information collected is then recorded by the tier-1 supplier and passed to the OEM. The tier-1 supplier then passes an uncompleted copy of the questionnaire to the tier-2 supplier.

**Step 5:** The tier-2 supplier uses the questionnaire to collect all needed information on the tier-3 supplier that is directly under it on the CSN path. The information collected is then recorded by the tier-2 supplier and passed to the tier-1 supplier who then passes it to the OEM.

**Step 6:** The process continues down the path to the tier-n supplier on whom needed information is collected by the tier-(n-1) supplier. The information collected by the tier-(n-1) supplier is then passed to the OEM through the n-2 higher-tier suppliers on its CSN path.

**Step 7:** Chose a new CSN path and go to step 4.

**Step 8:** Repeat steps 4 to 7 until there is no CSN path in the MMTSN in which all suppliers' information has not been collected.

**Step 9:** The OEM compiles all the information on all the tier suppliers in all CSN paths. It studies the information to identify problems and assess risks associated with each lower-tier. Each head of a CSN path also records all the information on all the lower tier suppliers on its network path and study the information to identify problems and assess risks associated with each lower-tier supplier on its network path.

How this procedure can be made more efficient is discussed in section 3.4. The possible actions that an OEM can take after applying the procedure and getting results are discussed in section 3.5.
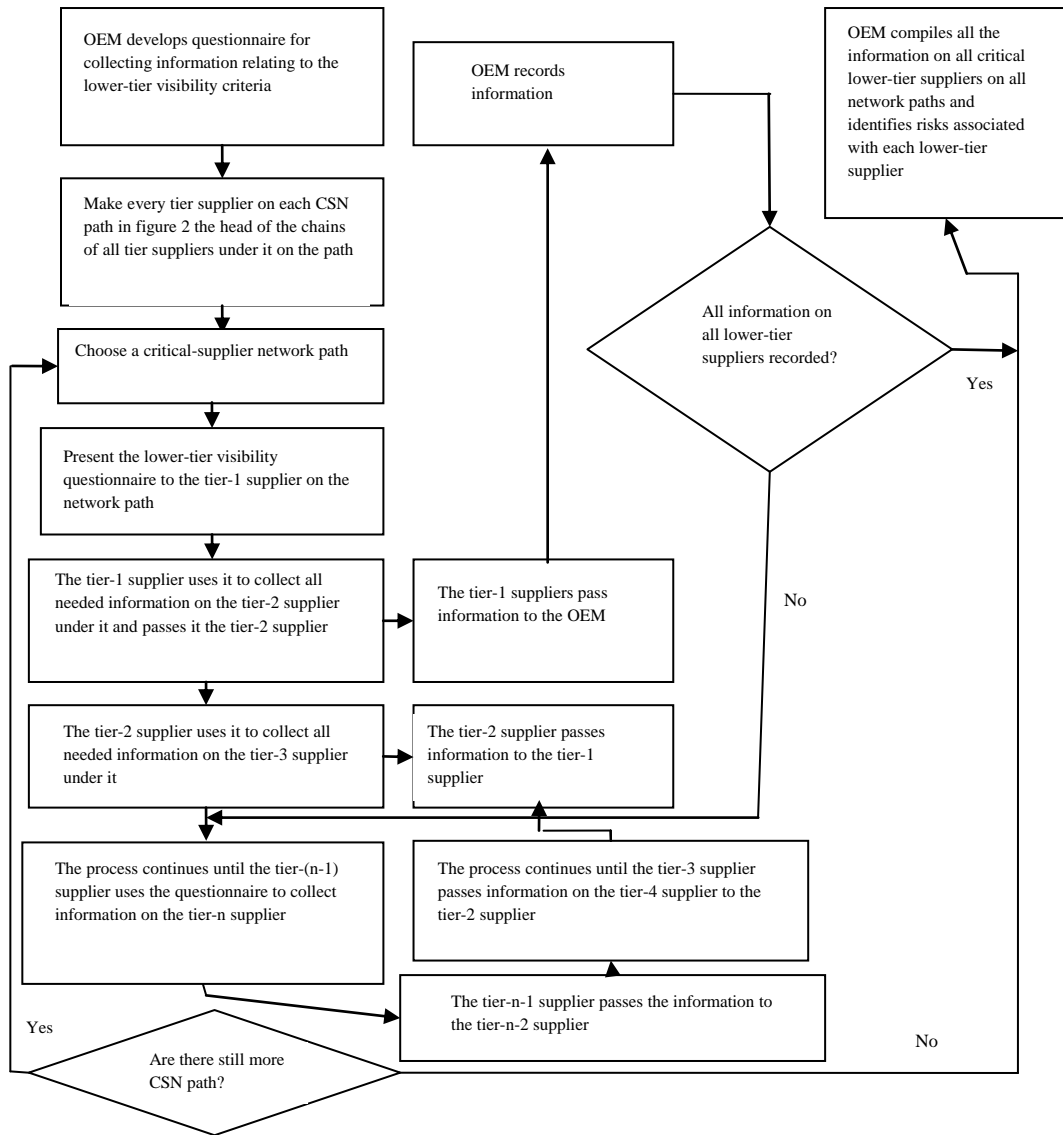
**Figure 4. *Process of establishing the visibility of tier suppliers***

### 3.3. The DD-and-SU Procedure for Using Scorecard to Continuously Maintain the Visibility of Every Critical Tier Supplier in MMTSN Systems

After establishing the visibilities of the suppliers on the critical network paths using the procedure in 3.2, the OEM must ensure that they are all continuously evaluated and monitored to continuously maintain their visibilities and to ensure that any emerging critical issue or risk in the MMTSN system is detected and addressed very timely and also to continuously improve the performance and efficiency of the supply chain. The process for doing this, using scorecard, is

presented below. The graphical illustration of the process is also presented in Figure 5 below.
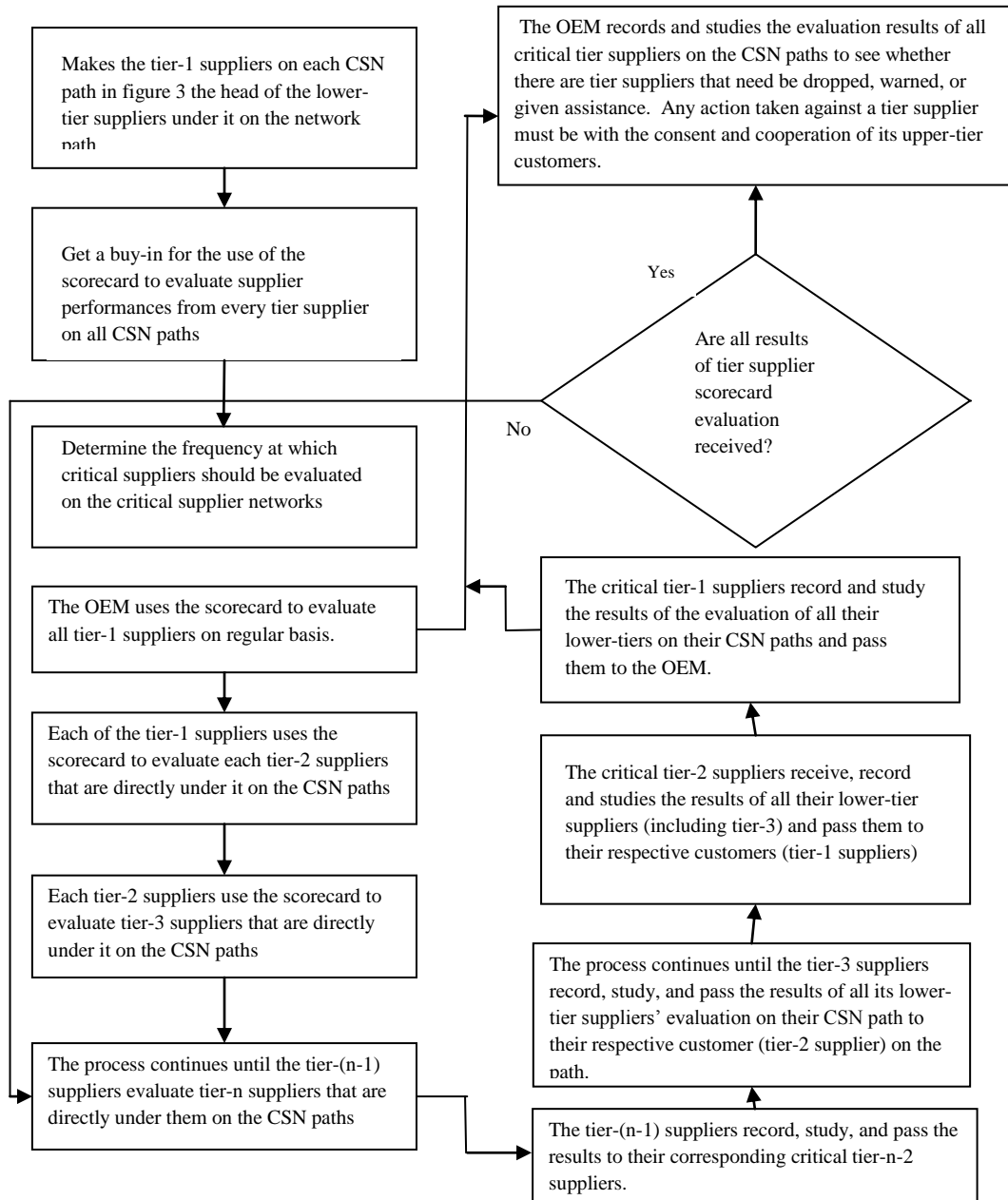


**Figure 5.** The process of using scorecard to evaluate the performances of critical suppliers on the CSN paths

The scorecard process steps for continuously maintaining the visibility of every critical tier supplier in MMTSN systems are as follows:

**Step 1:** Make the tier-1 supplier on each CSN path the head of its path. Every other tier supplier is also the head of the chain of tier suppliers under it on the network path.

**Step 2:** Discuss the importance of using scorecard for evaluating all tier suppliers (from tier-1 to tier-n) with each tier-1 supplier on each CSN path. Also, discuss the scorecard's goals, objectives, metrics, and targets with each tier-1 supplier and get a buy-in from them.

Each of the critical tier-1 suppliers also discusses the scorecard with the tier-2 suppliers

(Which are its direct suppliers) in its CSN path. The discussions and buy-in processes continue until every tier-n supplier (or every lowest-tier supplier) on each CSN path buys in into it.

**Step 3:** Determine the frequency at which each lower-tier supplier on each CSN path should be evaluating its immediate lower-tier supplier, i.e. whether scorecard evaluation should be done monthly, bimonthly, quarterly, half-yearly or yearly. Ensure that all lower-tier suppliers on each CSN path adopt and adheres to the frequency of evaluation.

**Step 4:** Use the scorecard to evaluate all the tier-1 suppliers on regular basis and record the results of the evaluation each time.

**Step 5:** Each tier-1 supplier on the CSN path uses the scorecard to evaluate the tier-2 supplier(s) (who is/are its own critical tier-1 supplier(s)) on the CSN path, on regular basis. It records the results of the evaluation and passes them to the OEM each time.

**Step 6:** Similarly to step 5, each tier-2 supplier on each CSN path uses the scorecard to evaluate the tier-3 supplier(s) (who is/are its own critical tier-1 supplier(s)) on its own path. It records the results of the evaluation each time and passes them to the tier-1 supplier (or its own immediate customer) on its own CSN path that passes the results to the OEM.

**Step 7:** If there are still more lower-tier suppliers in some or each of the CSN paths, then the process in 6 continues with each tier-3 supplier on each of the CSN path evaluating the tier-4 supplier in its own path, recording the results of the evaluation and passing them to the tier-2 supplier (or its own immediate customer) in the CSN path. Each tier-2 supplier then records the results and passes them to the tier-1 supplier or its own immediate customer in its own path. Each of the tier-1 suppliers also records the results and passes them to the OEM.

**Step 8:** The process continues until each of the tier-(n-I) suppliers uses the scorecard to evaluate the tier-n supplier in its own path and passes the results to the OEM through the chain of upper tier-suppliers in its own path.

**Step 9:** When a tier supplier who is a direct customer to a lower-tier supplier in a CSN path gets the evaluation results of a lower-tier supplier, it studies its performance to see whether it needs be dropped, warned, or given assistance/help (through supplier development program) that can make it improve its future performance. The tier supplier gives priority considerations to the comments/decision of the OEM on the lower-tier supplier in making a final decision. The comments/decisions of all higher-tier suppliers to the tier supplier making a decision are also considered.

## 3.4. Suggestions for Enhancing the Efficiency and Effectiveness of the Applications of the CP

Although the CP is not a complicated process and, therefore, it can be easily adopted and applied in organizations, its efficiency and effectiveness can be further enhanced if its application is based on good decision support platform/system (DSP/DSS). DSS can be used for collecting, storing, accessing, retrieving, transferring, and sharing information on tier suppliers along the different CSN paths in an organization's MMTSN system.

### 3.4.1. Information that can be collected, stored, and shared by OEM and tier suppliers

Information that can be collected, stored, retrieved, transferred, and shared in the applications of our CP using DSS include:

- CSN network paths.
- Information about tier suppliers' profiles.
- Tier suppliers' scorecard performances.
- Profiles and scorecard-evaluation performances of newly admitted suppliers into any tier-level of any CSN path.
- Profiles of any tier suppliers dropping out of a CSN path at any tier level.
- Information about any significant events/occurrences (internal and external) occurring at any tier-level.
- Information about SC activities, risks, and performances.
- OEM's and tier suppliers' production, inventory, and marketing information. (These are information that can follow after end-to-end multi-tier visibility has been established and well-sustained and the OEM has moved to the SC collaboration and/or integrations phase(s)).

### 3.4.2. A brief highlight of how DSS can be used to share, transmit, store, and access information

We are not developing a DSS for the application of our composite process in the paper. The focus of the paper does not include that. Developing one is another big and separate research of its own for another paper. A brief highlight of how DSS can used effectively for sharing, transmitting, storing, and accessing information during the application of each of the CP's procedure

### 3.4.2.1. How DSS can be used to collect, transmit, and share information during the applications of CP

If some sort of electronic connectivity (like electronic data interchange (EDI) or system applications and products II (SAP-II)) already exists in a MMTSN system between every customer and its suppliers (particularly its critical suppliers) ever before the application of the procedure in section 3.1, data collection can be easier and faster. In mapping and developing CSN paths using the procedure, a tier-k (1<k≤n) supplier can pass the lists of its own critical tier suppliers together with the list of all tier suppliers that has been passed to it by tier-(k+1) (or its own direct supplier) to tier-(k-1) (1<k+1≤n) supplier electronically. Thus, the electronic transmission of data can always be done in this way right from the lowest-tier or tier-n supplier to the OEM during the application of the procedure (the procedure in section 3.1).

It must be noted here that before the application of the procedure in section 3.1, any information systems that may exist in any supplier network path of the MMTSN system will always be limited to the ones that link customers to their direct or immediate suppliers on the path. Direct electronic connectivity between non-adjacent tier suppliers on the path may not exist. This is because an upper tier supplier will like to have a clear visibility of any lower tier supplier that is not its own immediate or direct supplier and establish relationship with it before it can allow its information system to be linked to that of the lower-tier supplier.

Due to the same reason given above, the process of collecting, transmitting, and sharing information electronically during the applications of the procedure in section 3.2 is the same as the process highlighted above for the applications of the procedure in section 3.1.

After the applications of the two procedures in sections 3.1 and 3.2, the OEM would have known all its CSN paths and all the tier suppliers in each path and establish relationships with them. Every tier suppliers would have also known all the tier suppliers on its CSN path and do likewise. One of the priority projects that should immediately be undertaken at this stage by the OEM is to develop a DSS that links it with all tier suppliers on the CSN paths and that also links every tier supplier with any other tier supplier. This will enable the maintenance of end-to-end multi-tier visibility in each CSN path, using the procedure in section 3.3, to be very efficient and effective.

During the application of the procedure in section 3.3, after a tier-k supplier (k = 1, 2, ……, n-1) has used scorecard to evaluate a tier-(k+1) supplier (its direct supplier) on a CSN path, it puts the result of the evaluation in its own (the tier-k supplier's) portal in the DSS where only itself, the upper-tier or downstream suppliers, and the OEM can access it using password. Since – as explained in section 3.3 - the OEM and every tier supplier on a CSN path knows when any of its lower-tier suppliers on the CSN path is evaluated, the OEM and any upper -tier supplier to a supplier that has just been evaluated can use its username and password to access the results of the scorecard evaluation on the portal of the evaluated supplier's direct customer or immediate upper-tier (that does the evaluation) very easily and quickly.

### 3.4.2.2. Access to stored information in the DSS

The DSS should provide different levels of access depending on the type of user and on the type of information. The OEM and every tier supplier should be able to access their information and any information about any downstream tier supplier that is on the same CSN path with them. A tier supplier should be able to access any information about the OEM or any other tier supplier except information about the scorecard performance of an upper tier or downstream supplier.

When SC integration/collaboration is in full operation along CSN paths, any tier supplier on a CSN path should be able to access the OEM's production, inventory, and marketing information. The OEM and any tier supplier on a CSN path should also be able to access any other tier supplier's production, inventory, and marketing information.

## 3.5. Follow-Up Actions that May be needed after Establishing the Visibility of Critical Tier Suppliers and After Each Scorecard Evaluation Cycle

After establishing a clear visibility of the critical tier suppliers at the end of the procedure in section 3.2 and after each scorecard evaluation cycle using the procedure in 3.3, the OEM would have got all important details about all suppliers on the CSN paths, including their strategic importance, financial viabilities, operational performance and capabilities, and risk profiles. If the OEM finds any critical tier supplier wanting, it has to work with the critical tier-1 supplier (or its own direct supplier) that is at the head of the CSN path of the "problem" tier supplier to address the issues it (the "problem" tier supplier) may have or to take any other appropriate action.

The co-operation and collaboration to take appropriate actions must involve all the critical tier suppliers on that path, right from the OEM's critical tier-1 suppliers to the "problem" tier supplier's immediate or direct tier customer. This is necessary as the OEM or a higher tier supplier should not establish any contact or take any decision or action on any tier supplier's supplier without the consent

and/or involvement of that tier supplier. Any decision or action the OEM or a higher tier supplier recommends or initiates on any tier supplier must be with the consent or approval of the tier supplier's immediate customer. The process of getting consent or approval for a decision or an action must be obtained via a "roll-down" or hierarchical process that starts from the OEM and ends with the "problem" tier supplier's immediate customer. If any higher tier supplier to the 'problem' tier supplier on that path disapproves, the initiated action or decision has to stop.

Among the decisions that the OEM or an upper-tier supplier can initiate or take are that a "problem" tier supplier should be:

i.    Continuously monitored.
ii.   Replaced with a new supplier, if a better one can be found.
iii.  Given help to solve the problems facing it.
iv.   Given warning and advised to improve its performance or work on the issues facing it.
v.    Made to undergo an appropriate supplier development program.
vi.   Taken over by any of the higher-tier suppliers or the OEM.

Whenever a new supplier joins a CSN path or replaces a supplier in a CSN path, the immediate higher tier supplier or its direct customer determines whether it is a critical supplier to it (to the direct customer). If it is a critical tier supplier, its direct customer then sends all detailed and relevant information that can make the OEM and all other tier suppliers on the CSN path have a clear visibility of the new tier supplier through to the OEM via all the upper tier suppliers on the new supplier's CSN path, beginning with its immediate customer. Through this, the visibility of any supplier in any CSN path will always be maintained throughout the path.

## 4. Summaries, Conclusions, and Recommendations for Future Research

### 4.1. Summaries

Our major contributions in this research include the developments of:

➢ A CP for establishing and maintaining end-to-end visibility in MMTSN systems. The process consists of a set of three procedures, namely:

- The DD-and-SU procedure for mapping and developing critical supplier network (CSN) paths in MMTSN supplier systems.
- The DD-and-SU procedure for establishing the visibility for tier suppliers in all CSN paths.
- The DD-and-SU procedure of using scorecard for evaluating every critical tier supplier in MMTSN systems.

> ➤ The steps to be followed in applying each of the CP's constituent procedure and an illustrative chart of the steps of each procedure.
> ➤ A list of Information items can be collected, stored, and shared by OEM and tier suppliers
> ➤ An outline of the procedure/process by which DSS can be used effectively for sharing, transmitting, storing, and accessing information during the application of each of the CP's procedure.
> ➤ A list of follow-up actions and decisions that may be taken after establishing the visibility of critical tier-suppliers and after each scorecard evaluation cycle.

The critical review of the approaches used in some industries for engendering the visibilities of tier suppliers is our another major contribution in the research.

### 4.2. Concluding Remarks

We see the developments of the CP and its constituent procedures (the three DD- and SU procedures) as very important contributions of our research to knowledge and to the advancement and improvement of SC practices.

Multi-tier supplier visibility has to be first established before being maintained and it has to be continuously maintained for the engenderment of SC visibility; SC integration, collaboration, and risk management to succeed. Our CP is developed for establishing and for effectively and continuously maintaining multi-tier supplier visibility. In particular, it will enable the OEM to continuously maintain the visibility of all its critical tier-1 and lower-tier suppliers down to tier-n in its MMTSN systems. It will enable it to continuously monitor their performances on important supplier performance metrics and targets using scorecard. Therefore, we see it (our CP) as an important bedrock for the success of any effort to engender the visibility of any SC and to foster its synchronization/integration and enhance its performance.

To the best of our knowledge of literature on multi-tier supplier visibility, the CP and its constituent procedures developed here are the first process/procedures that have ever been developed for establishing and for continuously maintaining the visibilities of tier suppliers' end-to-end in MMTSN systems. The presentations and critical reviews of some industry approaches for engendering lower-tier supplier visibility in section 2 also bear a very good testimony to this.

The CP is devoid of all the shortcomings of the industry procedures that are highlighted and reviewed in section 2. If adopted in industries, it will prove to be a very useful and effective tool for continuously engendering tier supplier visibilities and for integrating and synchronizing OEM's and tier suppliers' strategies, supplier relationship/development activities, operational plans and

activities, and risk management strategies  end-to-end across multiple-multi-tier supplier networks.


## 4.3. Recommendation for Future Research

The development of a DSS for the application of the CP developed in this paper is not a part of the focus of our research. Developing one is another big and separate research of its own for another paper. Therefore, we recommend that a research should be undertaken to develop a DSS for the applications of CP. Such a DSS will enhance the ease and effectiveness of information sharing, transmission, storing, and retrieval/access in the applications of CP. It will also make SC integration and collaboration to be seamlessly accomplished during any application of CP.

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