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An Integrative Framework for Coordination in Supply chain

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Abstract
Supply chain coordination relates to effective management of different disparate but dependant members/processes. Dependencies between various members and consequent coordination mechanisms to manage these dependencies are captured by proposing c-procurement (Coordinated- Procurement) model in this framework. The applicability of coordination theory has motivated to propose a holistic approach called as "Situation-Actor-Process- Learning-Action-Performance (SAP-LAP)" for exploring the status of coordination. The effectiveness of various coordination mechanisms is modeled through multi-criteria approaches based on Graph theory and Fuzzy logic. The extent of coordination is evaluated by qualitative study (based on the inputs given by practitioners) and simulation. The simulation approach also helps in assessing the value of coordination in terms of improvement in various performance measures related to coordination. The novelty of the integrative framework lies in combining a rich mixture of both qualitative and quantitative tools to address important issues in coordination and applying the same to a real-life case.

Key words: Supply chain coordination, coordination mechanisms, graph theory, fuzzy logic, simulation, Supply chain coordination index

Introduction

Supply chains are generally complex with numerous activities usually spread over multiple functions or organizations and over lengthy time horizons. Supply chain members cannot compete as independent members. The product used by the end customer passes through a number of entities contributed in the value addition of the product before consumption. To improve the overall performance of supply chain, the members of supply chain may behave as a part of a unified system and coordinate with each other. Thus "coordination" comes into focus. The continuous evolving dynamic structure of the supply chain poses many interesting challenges for effective system coordination. Supply chain coordination relates to effective management of disparate but dependant members/processes.

In any system the smooth functioning of entities are results of well-coordinated entities. So, it is very difficult to define coordination precisely. There is no unique perspective on coordination, but the lack of coordination can be easily articulated through a variety of surrogate measures.

The most applicable definition to supply chain is "managing dependencies between activities" (Malone and Crowston, 1994). There are different perspectives of coordination like at Individual level and organizational level and in the areas of Economics, distributed artificial intelligence and supply chain (Table 1).

"take in Table 1 here"

From the different perspectives of coordination, and as per coordination theory coordination in any system constitutes identifying different activities, dependencies between activities, performers of the dependent activities, means and mechanisms to manage those interdependencies between activities and roles, responsibilities and plans specified and standardized towards common goals. The coordination theory guides how the dependencies can be managed to resolve conflicts with mutual adjustment and cooperation. Analogous to coordination theory, the same type of system can be found in supply chain.

There are different models of supply chain coordination presented in literature based on

- Coordination between supply chain processes: Production-Distribution, Inventory-Distribution, Procurement-Production and multi-plant coordination.
- Difficulties in coordinating supply chain members: Differences in interests, opportunistic behavior, disagreements over domain of decisions and actions, inappropriate performance measures, misalignment of performance measures with overall supply chain, traditionally and outdated policies, failure to differentiate with whom to coordinate and lack of trust.
- Coordination models focusing on coordination issues: information sharing, decision making, information technology (IT), logistics synchronization, incentive alignment, trust among supply chain members and supply chain partnerships
- Multiple benefits accruing from effective coordination of the SC. Some of these include: elimination of excess inventory, reduction of lead times, increased sales, improved customer service, efficient product developments efforts, low manufacturing costs, increased flexibility to cope with high demand uncertainty, increased customer retention, revenue enhancements.

A lot of work in supply chain coordination has been done focusing on different aspects of coordination. There is scope to consolidate various aspects of coordination and need to handle following gaps in the literature:

- Mapping of coordination theory in supply chain may throw more light on tackling the problems of supply chain coordination.

- More emphasis is given on how to achieve coordination in a supply chain rather than defining it comprehensively in the context of supply chain.
- Supply chain coordination consists of both qualitative and quantitative issues, which need to be captured in an integrative model.
- There is a need to bridge the gap between coordination theory and practice with the help of case studies.
- There is a need to explore the importance of coordination mechanisms and their impact on supply chain performance.
- A holistic view of coordination mechanisms to coordinate all activities of supply chain is required along with a quantitative measure of coordinated supply chain.

The above gaps identified in the literature can be tackled from various viewpoints. A systemic inquiry in conjunction with coordination theory is required to explore supply chain coordination issues in some organizations with the help of conceptual and empirical models. The roles of coordination mechanisms in achieving coordination or evaluating may demand the application of combination of multi-criteria-decision-making (MCDM) models, analytical and simulation approaches. The proposed approaches for evaluation of coordination need to be applied in real life case studies so as to demonstrate their utility.

This gives motivation to propose an integrative framework consisting of various templates specific to the coordination problem domain. These templates present different issues of supply chain coordination, means and mechanisms of coordination, evaluation of supply chain coordination and exploring relationship between coordination mechanisms and performance measures of coordinated supply chain.

Integrative framework for supply chain coordination

The supply chain coordination is an evolving area and need to be strengthened by exploring it from theoretical as well as practitioner's point of view. The biggest challenge in supply chain coordination is to coordinate different and complex processes of supply chain involving human system (as supply chain members) with different interests. Supply chain coordination may be

achieved when a web like supply chain comprised (Figure 1) of different members act as part of one system.

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The supply chain members can be horizontally coordinated or vertically coordinated (Figure 1). The vertical coordination can be defined as the coordination between supply chain members located at different levels (for example: between supplier and manufacturer, manufacturer and distributor, distributor and retailer) of the supply chain and horizontal coordination can be defined as the coordination between different supply chains members located on the same level (for example : between various suppliers/manufacturers mostly for coordinated replenishments and standardized information systems) of the supply chain.

An integrative framework may help to cover the diversified issues of supply chain coordination with the help of different models described by different templates as follows:

1. Template 1: Coordinated Procurement (C-procurement) model
2. Template 2: Situation-Actor-Process-Learning-Action-Performance (SAP-LAP) model
3. Template 3: Analytic Hierarchy Process (AHP)- Fuzzy model (Independent coordination mechanisms)
4. Template 4: Graph theoretic model (Interdependent coordination mechanisms)
5. Template 5: Analytical model
6. Template 6: Simulation of analytical model
7. Template 7: Assessment of coordinated supply chain

A schematic diagram of the proposed integrative framework is shown in Figure 2.

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Coordinated Procurement (C-procurement) model

There seems to be fit between coordination theory and the integrating view of the supply chain:

- Interdependency is reality in supply chain and involves the outcome of the activities
- Output at one level becomes input for other level of supply chain, hence highly interdependent supply chain members
- The more specific the interdependency is identified, the deeper the level would be at which coordination strategy can be executed
- Two types of objects involved in the dependency: customer related tasks and the resources used to accomplish the task

- Task refer to what has to be done or to be realized such as customer order and production order
- Resources refer to what is being used or created by the activities to realize tasks, such as organization, capacity, inventory, backlog and money (Li et al., 2002)

Based on the fit or mapping of coordination theory, the supply chain coordination can be defined as Identifying:

1. Different interdependencies among supply chain members like dependent activities: ordering, procurement, inventory management, production, design and development, replenishment, forecasting and distribution;
2. Complexities in managing the above mentioned interdependencies;
3. Different coordination mechanisms to tackle the complexities in managing the interdependencies like resource sharing, knowledge sharing, information sharing, joint working, joint decision making, joint design and development of product, joint promotions, implementing information systems, designing risk sharing contracts; and
4. Control variables, which can capture the value of coordination in terms of improvement in the performance measures in the best interests of all supply chain members to achieve win-win situation.

The Coordinated-procurement (C-procurement) model is proposed to demonstrate the applicability of coordination theory in procurement process of supply chain described as Template 1 presented in Table 2. The thirteen number of activities of traditional procurement process after applying coordination theory can be reduced to five interdependencies.

- Supplier selection and development
- Contracts related to supply management
- Order management
- Joint Operations Planning
- Relationship development

"take in Table 2 here"

It can be observed that different coordination mechanisms like contracts, information technology, information sharing and joint decision making and various coordination enablers like Electronic Data Interchange (EDI), Efficient Consumer Response (ECR), Continuous Replenishment Process (CRP), Vendor Managed Inventory (VMI), Collaborative Planning, Forecasting and Replenishment (CPFR) helps in coordinating complex activities of procurement

process. Some of the activities can be coordinated simultaneously reducing the time to carryout the activities and improving the efficiency of procurement process.

The same concept can be extended to coordinate other processes of supply chain like production and distribution process. The application of coordination in real life case study may help to explore other issues of coordination for example what is the perception of coordination in some organization? What are the qualitative and quantitative factors of coordination? What efforts the organization takes to coordinate intra-organizational as well as inter-organizational system? How flexible these systems are to adopt coordination mechanisms?

Situation-Actor-Process (SAP)-Learning-Action-Performance (LAP) model

In context of supply chain coordination, a systemic model is required to consider the overall view of coordination and the flexibility required to implement the coordination mechanisms in the whole supply chain system. Flexible systems management has provided the concept of flexibility, which can be used in managerial context to study the qualitative and quantitative factors in any system. A Situation-Actor-Process (SAP)-Learning-Action-Performance (LAP) model of a flexible system is proposed by Sushil (2000), which can be implemented to explore supply chain coordination issues in some real life case study.

Supply chain coordination can be achieved by joint efforts of dependent members of supply chain. A real life case study may help to explore various factors and the efforts required by an organization to coordinate at individual level, at organizational level and at inter-organizational level (may be of qualitative or quantitative in nature). The SAP-LAP model gives flexibility to include both types of factors in which, the 'situation' represents the present status, environment of an organization, and the driving forces for good performance of an organization. 'Actors' are the individual participants, or group of members, which influence the situation and define an

organization culture to evolve business processes. The 'process' is an overall transformation process that converts a set of inputs into outputs to recreate the situation. The interplay and synthesis of SAP leads to learning-action-performance (LAP) in which various learning issues are brought out regarding situation-actor-process (explained as Template 2 in Table 3). Based on the learnings, action is to be taken on the front of SAP or the interface. The impact of the action on the performance can be analyzed for the improved performance of actors or processes and situational parameters.

"take in Table 3 here"

The actors might have different perceptions of coordination, as the actors in supply chain may not be restricted to one organization only. The actors belong to different organizations of same supply chain and they perform different activities and processes. To coordinate with each other, the actors have to be flexible enough to understand and adopt the coordination perspective of other actors of supply chain. The capability to understand coordination perspectives of different actors also demands a good understanding of the flexibility associated with the situation and the coordination processes in an organization. So, an inquiry in flexible manner is required to explore coordination issues in an organization. The flexible model of SAP-LAP along with internal and external environment also considers the impact of dynamic environment on inter-organizational systems and intra-organizational systems. It seems that the traditional models are not able to capture the overall gamut of supply chain activities in a holistic manner. The traditional models are also weak in capturing the dynamics of changing environment and flexibility required to face dynamics. The proposed model not only discusses the issues of coordination only but also explains how to work on the issues, potential lie for some change, the impact of change, the extent of change and the flexibility required to adapt the change.

Flexibility required coordinating with supply chain members

The coordination initiatives give good results only when they are followed jointly and harmoniously. There should be an environment where the people can share knowledge, understanding, and values to achieve mutually beneficial goals. Flexibility is required in adoption of compatible and standardized information technologies like EDI and initiatives like VMI. Some standardized information systems are required at each level of supply chain. Skill, knowledge and awareness of recent information technology are very important to communicate with other supply chain members. The supply chain actors are expected to be flexible to face the changes in the processes.

Interplay of SAP

The coordination situation can be managed if the actors have the vision to adapt to flexible process and adopt different coordination mechanisms. The adoption of coordination mechanisms help in recreating the situational parameters. To deploy the concept of coordination, the knowledge and understanding of the present coordination situation and processes are required by the actors. The actors may demand more freedom of choice to change the present concept of coordination in a more flexible way. The actors may share values, knowledge, and willingness with other actors at intra-organizational (between various business processes of organization) and inter-organizational (amongst different members of the chain) level. These organizations have different culture and different organization structure. The actors need to be flexible to adopt the concept of coordination of different organizations and are able to understand and implement the coordination mechanisms.

The processes of designing, procuring components, manufacturing and distributing, may change when actors adopt different coordination mechanisms (like information sharing, joint decision

making, meetings, information technologies and supply chain contracts). Accordingly supply chain processes can be reviewed and revised.

The various learnings could be the willingness to share information, provision of transfer of clear and quick information, knowledge to understand the information and information system, and zeal to work jointly by developing more trust between the organizations, which may result in a smooth and uninterrupted communication. The action in the form of implementing coordination mechanisms will help in placing all supply chain members under one system. More the flexibility to adopt these mechanisms more will be the improvement in the performance of the members as well as whole supply chain.

The SAP LAP model is a useful tool in understanding supply chain coordination perspective. Situation, actor and processes are different parameters even though inseparable, and LAP helps to synthesize SAP. This makes SAP-LAP a whole system. Supply chain is comprised of different organizations but because there is dependency between them, they may perform well when they consider themselves to be a part of one system. The utility of SAP-LAP model can be appreciated from studying the present situation of coordination, which may motivate the actors who may initiate coordination and the allied processes. Also, this model helps in identifying flexibility gaps in adoption of coordination mechanisms. The synthesis of SAP to LAP bridges the gap of flexibility by suggesting improvement actions based on the gaps of flexibility or the learning from the present situation, actors and processes.

Observations from the model Template 1 and 2

- There is an ample scope for application of coordination theory in organizations as clearly demonstrated through c-procurement model.
- A number of activities can be coordinated both in upstream and downstream members.
- There are various means and mechanisms (both qualitative and quantitative required to coordinate.
- The coordination mechanisms improve the performance of activities and whole supply chain.

- More than one coordination mechanism may be required to coordinate even a single process of supply chain.
- The proper implementation of coordination mechanisms, and the performance measures improved by implementing mechanisms can help in proposing a quantitative coordination measure,
- Some of the qualitative elements of coordination like coherent decision-making and mutual decision-making in conjunction with coordination mechanisms can be captured with the help of an analytical model.
- The aggregation of analytical model and MCDM models, when applied to the case studies can help in presenting the importance of coordination at the interface of supply chain

Coordination mechanisms

A coordination mechanism is a set of methods used to manage interdependence between organizations (Xu and Beamon, 2006). The two models presented above help organizations to apply coordination theory in their organization and come out with the set of coordination mechanisms. Based on the importance of mechanism in literature, c-procurement model and SAP-LAP model, four coordination mechanisms as (explained in Table 4) are categorized as:

1. Supply chain contracts
2. Information Technology
3. Information sharing
4. Joint decision making

Supply chain contracts are agreement between supply chain members which formally rule the transactions between the members and latter utilize incentives (risks and rewards) to make supply chain members decision coherent with each other (Koulamas, 2006). The profit maximization is the most commonly used performance measure while evaluating supply chain contracts. The contracts are designed at the very start of some relationship or start of the order cycle.

"take in Table 4 here"

The fast information systems have enabled the supply chain members to reduce the time related to the transactions pertaining to ordering. The members can send orders online through

information systems like EDI and email in a more detailed form. Information systems help in transferring the accurate information in less time, which reduces the response time (Swaminathan and Tayur, 2003)

Supply chain members may share information regarding end customer demand, inventory, capacity, production and delivery schedules, lead times and service levels to reduce inventory related costs and also to reduce the overall supply chain costs (Reddy and Rajendran, 2005).

Joint decision making for planning, ordering, replenishment, forecasting and mutual benefits sharing helps to resolve any exceptions that may crop up in future. Various collaborative initiatives can be used to jointly plan activities like VMI and ECR (Cheung and Lee, 2002).

There can be two cases of considering coordination mechanisms to evaluate some measure of coordination:

1. Independent coordination mechanisms
2. Interdependent coordination mechanisms

Independent coordination mechanisms

There can be an independent decision by some organization to implement the coordination mechanisms. The supply chain contracts may be designed regardless of whether the members will share operational information, use IT and will take collaborative decisions to reduce uncertainties. The decision regarding sharing of information is independent of other mechanisms that are contracts, Information Technology and collaborative decision-making. This is true that Information technology will help in fast sharing of information. But it may not directly effect the decision of sharing information i.e. the information can be shared without using new IT systems. Also, if the focus is on the practice of sharing information and its impact on inventory related issues, and then which mode of information technology is used may not affect the decision of information sharing. The end customer demand is uncertain and even if there is proper

information-sharing firms may face stock outs and more inventory costs, if the decisions are not taken jointly.

In case of independent coordination mechanisms the methodology adopted for evaluating coordination measure is AHP-Fuzzy approach, which is discussed in Template 3 presented in Table 5.

"take in Table 5 here"

The importance given to certain coordination mechanism may vary depending on the type of industry, the objective of supply chain and the interface or process of supply chain. The complexity in taking all these categories is that these are lying in different domains and some of the categories are supported by subjective judgments like behavioral aspects (trust, commitments, and cooperation) in coordination initiatives. These judgments may be vague in nature and difficult to quantify. Fuzzy system models are flexible enough to take these imprecise and vague data (Ross, 1997). Its multiple attribute decision-making property has motivated to propose the model in fuzzy environment. The linguistic terms assigned to the various categories will help in considering all four categories regardless of different domains of this classification. The model has also been applied to real life example of an auto component manufacturer.

Interdependent coordination mechanisms

Some of the supply chain activities have to be performed simultaneously. These activities may require two coordination mechanisms at the same time to accomplish the activity of supply chain. The interdependency between coordination mechanisms also impact on the extent of coordination or measures of coordination in some organization. Earlier presented model on AHP-fuzzy may not be able to consider the interdependency between coordination mechanisms. The interdependency can be of two-way interaction, three-way interaction and four-way interaction.

Two-way interaction

There can be a situation where two coordination mechanisms out of four are interdependent. While designing supply chain contracts, the supply chain members need to know the information on cost and price data of all supply chain members intended to coordinate. Also, the contracts

may give better results when the demand information is also shared among supply chain members. In this way supply chain contracts and information sharing are dependent on each other.
The other very common example of two-way coordination is information sharing and information technology. The information regarding orders and lead-time when communicated through fast information system, reduces the information and transportation lead times. Hence, information sharing and information technology are interdependent on each other.

Three-way interaction
The three way interaction is visible in the situation when jointly decide about forecasting and replenishment activities of supply chain by using joint decision making as coordination mechanism. The joint decision-making is complemented, when members share their individual forecasted information with each other and decide to operate on standard information system to timely share the information.

Four way interaction
The example of four-way interaction is apparent when along with the example of three-way interaction the supply chain members design contracts also. They may offer quantity flexibility contracts, so that any discrepancy because of forecasting demand can be adjusted by introducing flexibility in order quantity in whole supply chain.
The examples of various kinds of interactions illustrated above are few examples of many combinations of such interactions in real life supply chains. Such interdependencies can be captured by Template 4 presented in Table 6 to evaluate the extent of coordination with a quantitative measure.

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The graph theoretic approach presents a comprehensive measure of coordination comprising coordination mechanisms and the interdependencies between coordination mechanisms. The advantage of using the graph theoretic model is that all coordination mechanisms can be considered as sub-systems and the evaluation of qualitative measures for all coordination mechanisms can be determined by identifying the sub-factors of coordination mechanisms and the corresponding interdependencies between sub-factors (Deo, 2004)

The multi-criteria decision making models discussed in the context of coordination focus on the implementation of coordination mechanisms in some organization. There is further need to study how these coordination mechanisms will be implemented. For example an analytical study may help to explore how step-by-step implementation of coordination mechanism and determination

of corresponding decision variables helps to improve the performance measures of supply chain? An analytical study may help to realize the importance of coordination in the form of some performance measures and control on coordination by selecting decision variables of coordination mechanisms in the best interests of all supply chain members. To demonstrate such a control on coordination, an analytical model is proposed by considering the case of coordination mechanism: supply chain contracts in Template 5 presented in Table 7.

"take in Table 7 here"

Here, the best interests of supply chain members are captured by introducing the elements of coordination like Interdependency, Coherency and Mutuality as defined below:

a) Interdependency: Interdependency can be defined as when actions taken by one referent system affect the actions or outcomes of another referent system (Malone and Crowston, 1994). The supply chain members are interdependent on each other for the transfer of money, quantity and information. The supplier (upstream member of supply chain) relies upon buyer (downstream member) because of economies of scale, reputations of downstream members and downstream member's knowledge about local market. Interdependency is inherent in supply chains: members may be interdependent due to mutual information needs, transfer of funds and flow of physical units from one member to other.

b) Coherency*:* Coherency can be defined as the degree of consistency of reasoning across organizational borders through diffusing common understanding (Simatupang et al., 2002). The supply chain members are expected to make decisions in coherence with the whole supply chain. The quantity floating in supply chain must be the optimal order quantity for whole supply chain.

c) Mutuality: The mutuality of coordination can be defined as the underlying values of responsibility among partners with a strong emphasis on sustaining relationship in order to build effective goal attainment. The literature on social contract has recognized that any relationship among business partners must contribute to a climate of mutuality (Campbell, 1997). The mutuality norm suggests that each partner contributes to significant values and is entitled to an equitable and fair distribution of outcomes. In a typical supply chain, these outcomes could be: revenues generated, net profits and mutual sharing of risk (overstock/understock). The contract parameters are decided mutually so that the expected profits of all members are more than the case of 'no coordination'. Typically, the contract parameters include: cost and price related information.

Achievement of these elements is also good indicator of supply chain coordination. The cases of coordination can be compared with the case of no coordination determined by newsboy model (Nahmias and Smith, 1994).

Relationship between coordination mechanisms and performance measures

The analytical model gives the relationship between coordination mechanism and performance measures. This analytical model presents various inequalities to achieve coherency and mutuality. The relationships from analytical model can be simulated to generate various scenarios to gain managerial insights. A brief description of simulation is presented in Template 6 (Table 8).

"take in Table 8 here"

Simulation helps to quantify the analytical model. The behavior of some of the performance measures can only be analyzed when we can simulate the model by assuming some data as a starting point. The 'what-if' scenarios give more clarity about the feasibility of decision variables of coordination mechanism. It may also help in knowing what the control variables are. Once the coherency and mutuality is achieved, the value of coordination can be realized in the form of improving performance measures. That means there is not a single performance measure but a number of performance measures can be improved for all supply chain members coordinating with each other. These improving performance measures are indicators of coordinated supply chain, hence an aggregate assessment is required representing the improving performance measures. The Template 7 presented in Table 9 can be used to evaluate the effectiveness of coordination between supply chain members or supply chain. The changes in contract parameters change the decision variables of contracts and performance measures. The number of performance measures may also vary with input data of contract parameters. The percentage improvement of various performance measures is different for different supply chain members. A multi-criteria decision making methodology is required which can accommodate the change in the number of performance measures as well as the change in the percentage improvement in the performance measures.

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Managerial insights from different templates

Today's main concern in the area of Operations Management (OM) is how to bridge the gap between theory and practice. An integrative framework has been proposed keeping in view the blend of theory and practice. The proposed framework gives simple steps in the form of various templates to understand supply chain coordination from a broader perspective and to identify various coordination mechanisms suitable to coordinate particular kind of supply chain (Figure

3). Once the coordination mechanisms are selected, the managers can start working on implementing coordination mechanisms and evaluate their coordination capability on the basis of the performance measures of coordinated supply chain. The framework and various templates have following managerial implications:

- The identification of interdependent activities of supply chain will help to cover broader aspects of coordination.
- The identified interdependent activities may guide managers to implement coordination mechanisms suitable to coordinate particular activity of supply chain.
- Once coordination mechanisms are selected, the managers can evaluate the extent of coordination by using MCDM model. The brainstorming session among managers may help to assign weights according to the importance of coordination mechanisms.
- Template 3 and 4 helps to evaluate coordination at organizational level; hence the templates help in selecting supply chain members based on the extent of coordination of the member. Templates 3 and 4 are easy to understand and implement by managers as qualitative measures or linguistic terms are used to assign weights for various coordination mechanisms.
- Template 4 may also guide the managers about which link or interdependency between coordination mechanisms is weak and can be improved by taking some actions. The actions can be planned based on the sub-factors of coordination mechanisms.
- Template 5 may help managers in defining relationship between profit function of each member of supply chain and various performance measures. The introduction of coherency and mutuality may result in win-win situation for supply chain members (such as by using buyback contracts, the retailer is expected to order coherent or optimal order quantity of supply chain and in the same time he is allowed to return unsold units at the end of season. Hence, a situation, which improves the profits of supply, chain members from independent working).
- Template 5 gives an idea about the potential performance measures and indicators of coordination in supply chain.
- The simulation of analytical model can act as a decision-making tool helps in planning the activities before the actual activity begins. It gives an idea to the managers regarding on which variables and parameters of coordination mechanisms, they have direct control. It may also help in handling some exceptions, which may crop up in future by joint decision making
- Template 7 helps in evaluating coordination at the interface as well as of whole supply chain. The performance measures of all supply chain members quantified with the help of simulation ay use the graph-theoretic model to consolidate the overall performance of all supply chain members. The further usage of graph-theoretic model on the consolidated performance measures of each member helps in evaluating coordination in whole supply chain.

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Novel features of the propose framework

The integrated framework proposed covers a broader aspect of supply chain coordination. The strength of the framework lies in the fact that the framework has been viewed from different perspectives using various templates. Each and every template is required and important to present a right combination of theory and practice. The linkages can be observed from Figure 3 between the proposed templates. The outcome of each template can be used to propose another template. The various linkages between templates and the importance of each link are presented below:

- Linkage from Template 1 to Template 2: The application of coordination theory can be also be used empirical model in the form of case study to select the important coordination mechanism required by some organization
- Linkage from Template 2 to Template 3 and from Template 2 to Template 4: The evaluation of coordination requires the important coordination mechanisms to evaluate the overall importance of coordination. Hence, Template 3 considering the relative importance of coordination mechanisms without interdependencies need output from Template 2. Template 4 evaluates coordination by considering interdependencies also use the outcome of Template 2.
- Linkage from Template 3 to Template 2 and from Template 4 to Template 2: The MCDM models proposed in Template 3 and Template 4 needs to be applied in real life case study. The importance of various coordination mechanisms and the relative weights of coordination mechanisms given by managers of some organization helps in evaluating the extent of coordination in an organization.
- Linkage from Template 5 to Template 6 and from Template 6 to Template 7: The relationship developed between profit function of all supply chain members and various performance measures are required to be quantified with the help of simulation. The outcomes like the inequalities regarding finding the decision variables of contracts in Template 5 may help to achieve coherent order quantity and mutually beneficial performance measures in Template 6. The outcomes of Template 6 in the form of quantified performance measures may be used to assess the overall performance of coordinated supply chain in Template 7.
- Linkage from Template 4 to Template 7: The same methodology discussed in Template 4 is required to be adopted in Template 7. The various performance measures are consolidated to evaluate overall impact of performance improvement by using contract for each supply chain member in Template 7 by using Template 4. Again, the model in Template 4 is applied at the interface or for whole supply chain, where the diagonal elements of supply chain coordination structure in Template 7 is the consolidate performance measures of each member.

The linkages presented above shows that how the various templates are inter- related and cannot be dealt in isolation. It also helps in bridging the gap between theory and practice of supply chain coordination, which is the need of today. The various scenarios (with the help of analytical

model) generated in Template 6 may help in controlling coordination and help the managers to plan in advance the future actions of supply chain. The blend of theory and practice in the proposed integrative framework may be of great utility for the academicians to realize the importance of coordination in supply chain.

Conclusions

The study in supply chain coordination is still in its infancy. Supply chain coordination is the main concern for the academicians and practitioners. The work related to supply chain coordination reported in the literature is spread over various activities of supply chain discussed in isolation. There is a need to propose a framework to integrate various efforts of supply chain coordination, so that the importance of coordination in supply chain can better justified. The integrated framework helps to develop coordination theory in supply chain, so that each and every aspect of supply chain coordination can be explored. This developed theory may be applied in the context of supply chain so as to present the possible activities need coordination.

The further implementation of coordination theory in real life case study with a systemic inquiry about coordination may throw more light on the importance of supply chain coordination. It shows that how the implementation and usage of coordination mechanisms help in achieving supply chain coordination.

The theory building followed by empirical model helps an organization to select coordination mechanisms predominant in coordinating most of the activities of supply chain of an organization. Once the selection of coordination mechanisms in an organization is done, the overall view of supply chain coordination can be consolidated with the help of MCDM models. These models can be applied to real life problems to present managerial implications of these models.

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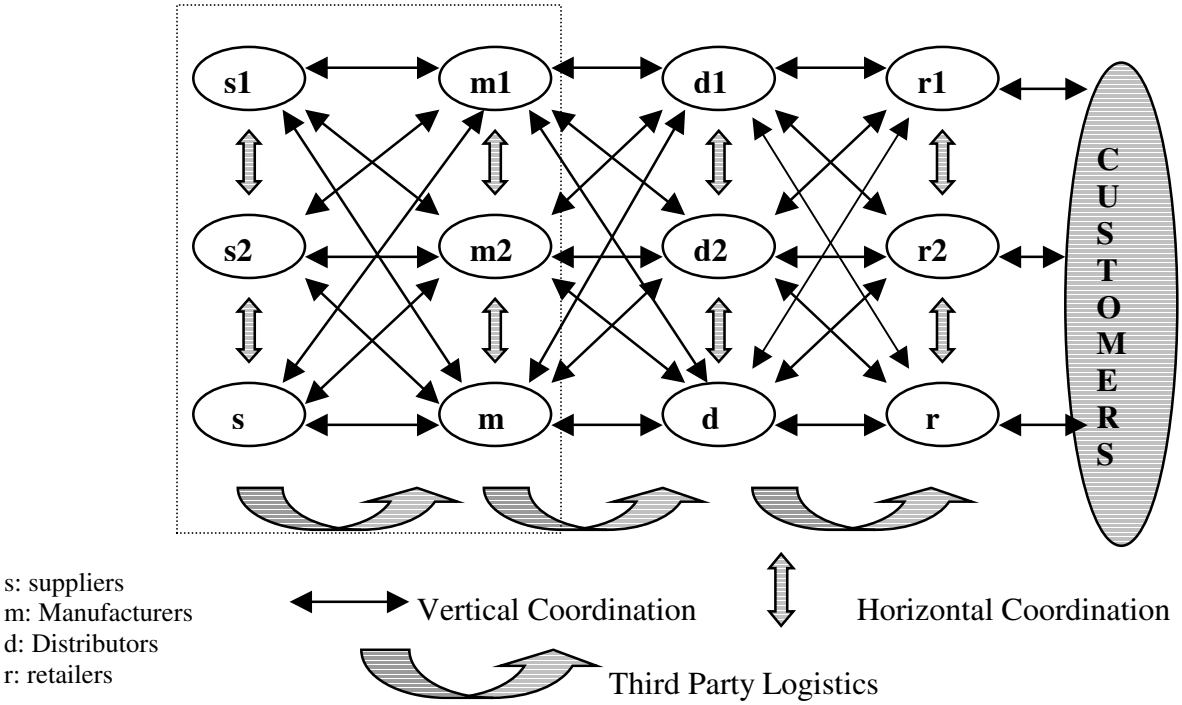

Figure 1: Supply chain coordination between various supply chain members

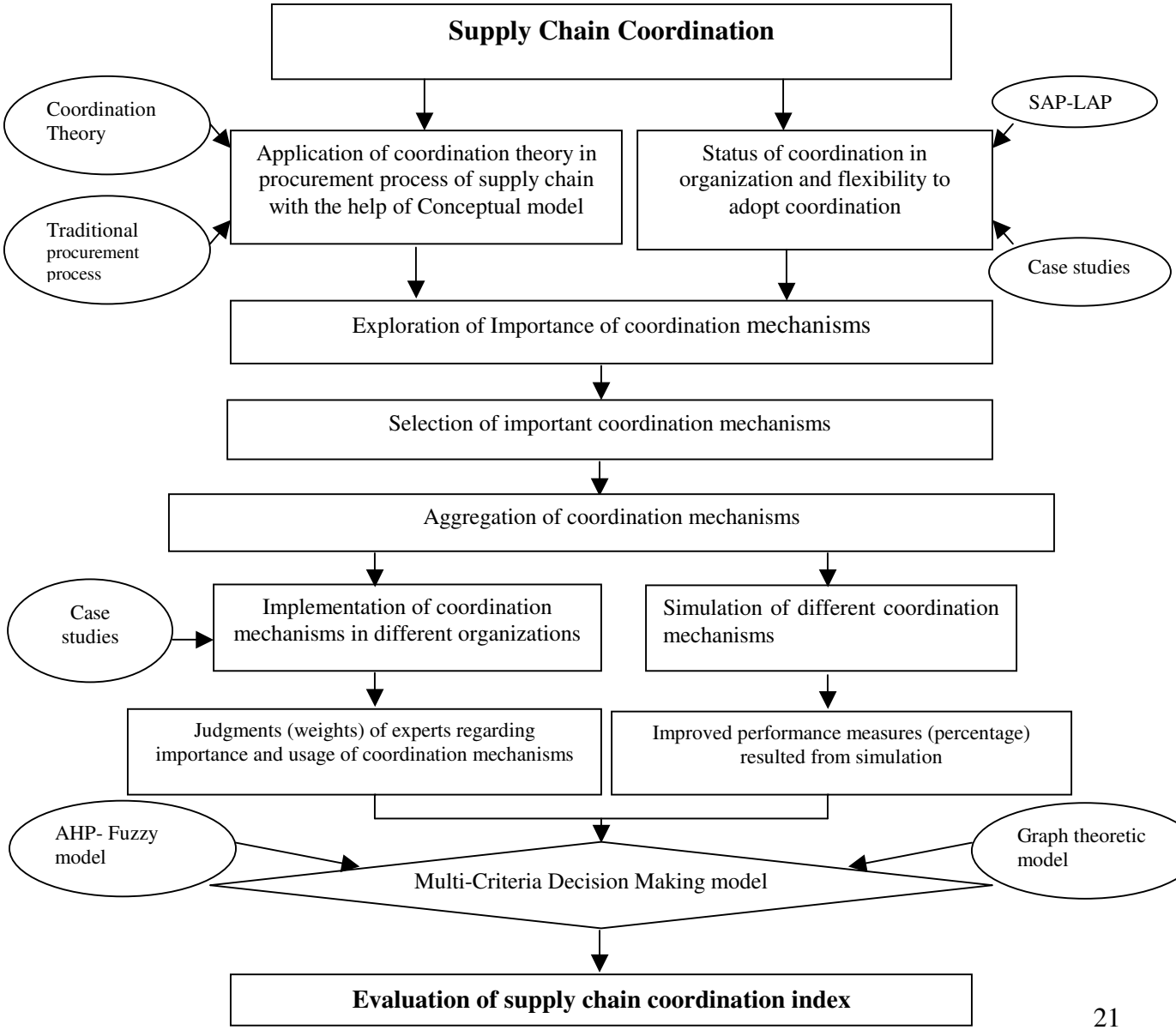

Figure 2: A schematic diagram of integrative framework of supply chain coordination

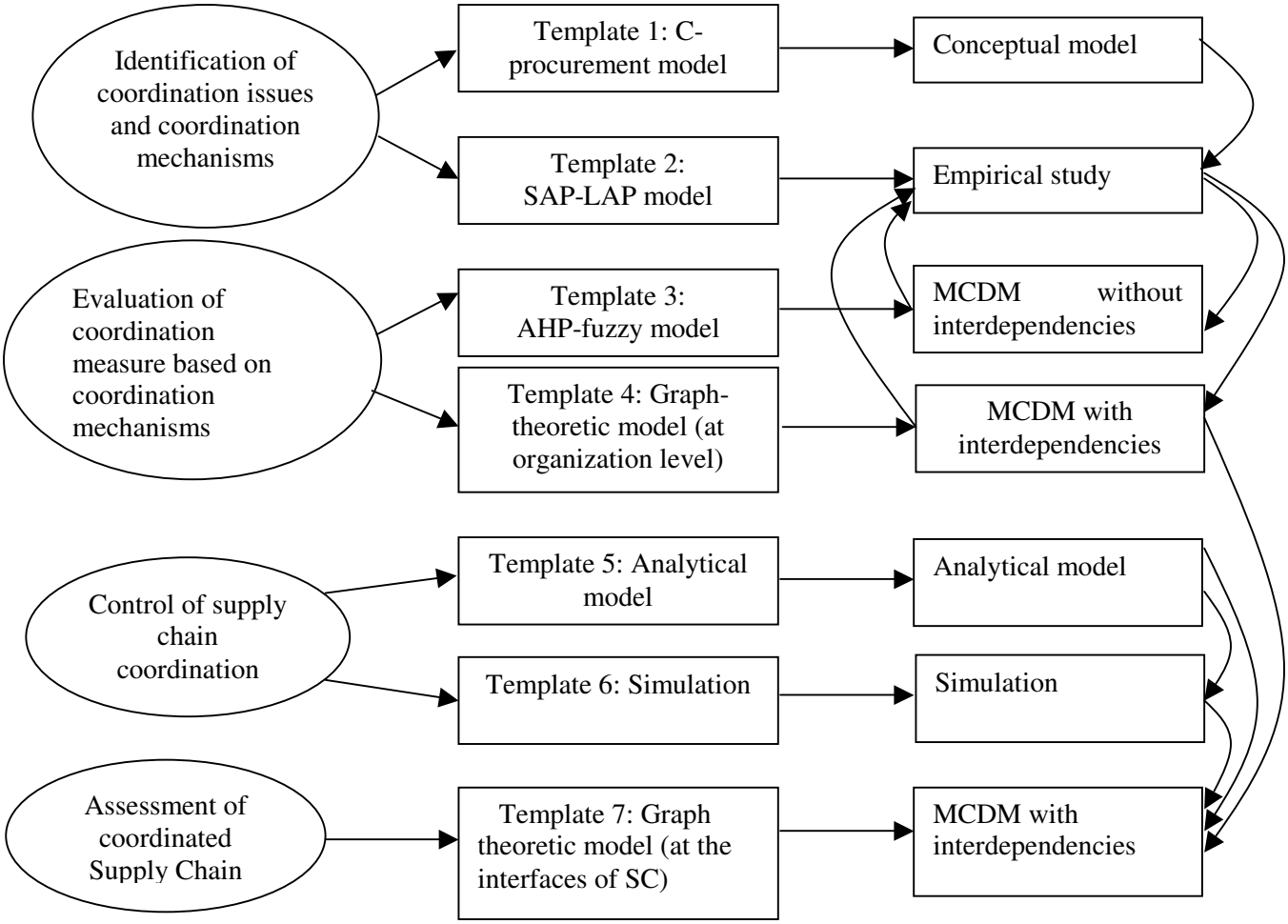

Figure 3: Various modeling Templates used in the integrative framework

Table 1: Various Perspectives on supply chain coordination

Author (year)	Perspective	Context
Robins (1987)	Matching supply and demand and producing the greatest consumer surplus to improve the economic efficiency	Economic coordination
Mintzberg (1979)	The management of interdependencies among different activities divided among different actors with coordination mechanisms such as standardization, direct supervision and mutual adjustment	Organization theory
Singh (1992)	The integration and harmonious adjustment of individual work efforts towards the accomplishment of a larger goal	Individual coordination
Chaib-Draa et al., 2004	The management the flow of information to coordinate the groups of agents	Distributed artificial intelligence
Narus and Anderson (1996)	Cooperation among independent but related firms to share resources and capabilities to meet their customers' most extraordinary needs	Resource sharing
Lambert et al. (1999)	A particular degree of relationship among chain members as a means to share risks and rewards that result in higher business performance than would be achieved by the firms individually	Risk and reward sharing
Simatupang et al. (2002)	Given the nature of the interdependencies between units, coordination is necessary prerequisite to integrate their operations to achieve the mutual goal of the supply chain as a whole as well as those of these units	Mutuality
Hill and Omar (2006)	Coordination can be achieved when the supply chain members jointly minimize the operating costs and share the benefits after jointly planning the production and scheduling policies	Joint decision-making, benefit sharing

Table 2: Description of Coordinated-Procurement model

Template 1
Name: Coordinated procurement (C- procurement) model
Objective: Application of coordination theory in procurement process of supply chain
Inputs: Coordination theory, traditional activities of procurement process, types of coordination, coordination mechanisms and coordination enablers
Brief description: The traditional procurement process consists of many steps, which can be coordinated and reduced to smaller number of effective steps. The activities in the procurement process can be classified as interdependencies in procurement process. By identifying the interdependencies, it is easier to coordinate some of the activities simultaneously. Since, each activity of procurement process is required to be coordinated, coordination mechanisms play important role in coordinating all activities of supply chain. The models also emphasize the need for various coordination enablers to help in coordinating both vertically and horizontally.
Outcome of the model: A coordinated (C-procurement) model is proposed by applying coordination theory step by step in all activities of procurement process.
Linkage to other Templates: Template 2
Reference: Arshinder et al. (2006 (a))

Table 3: Description of SAP-LAP model

Template 2
Name: Situation-Actor-Process-Learning-Action-Performance (SAP-LAP) model
Objective: Systemic inquiry of coordination issues in supply chain and the adoption of coordination mechanisms in an organization
Inputs: An inquiry of real life case study for present situation of coordination, efforts of coordination by actors, the processes required for coordination
Brief description: The model, with the help of case study of an auto component manufacturer, XYZ, helps in consolidating various perspectives and efforts required to coordinate by various actors of supply chain, and different processes, which enhances coordination situation at intra-organizational and at inter-organizational level. The SAP leads to various learning issues about the success factors, core competencies, coordination mechanisms, difficulties in achieving coordination and flexibility required to adopt the concept of coordination. Based on these learning issues, corrective actions may be suggested to improve the supply chain coordination as well as the flexibility required to implement different coordination mechanisms
• The "situation" presents an assessment of climate conducive or otherwise for coordination in an intra-organizational system. • The perspective on "Actors", helps in understanding the roles and responsibilities of various entities in the supply chain. • Assessment of "processes" helps in diagnosing the contributions of processes with a view of eliminating some non-value added processes thereby making the entire chain streamlined and focused. • "Learning, Actions and Performance" helps in identifying weak spots in the organizations from coordination point of view and motivating for improvements. • The same concept of coordination in intra-organizational system can be extended to interorganizational system by understanding the needs of other actors, objectives,

technology, schedules, expectations, and flexibility. • The model can be used in a 'self-assessment ' mode or as a benchmarking tool.
Linkage to other Templates: Template 1, Template 3 and Template 4
Reference: Arshinder et al. (2007)

Table 4: Characteristics of different coordination mechanisms

Coordination mechanism	Description	Different types	Advantages
Supply chain contracts	The contracts may specify the parameters (like quantity, price, time, and quality) within which a buyer places orders and a supplier is obliged to fulfill them.	Buyback, revenue sharing, quantity flexibility and quantity discounts	• Reduces risks of overstock/ understock costs • Provides incentives to all supply chain members • Improves the customer service level • Helps in countering double marginalization • Increases the profits of whole supply chain • Enhances flexibility in price and quantity
Information Technology	The supply chain members may communicate with each other through fast and flexible information systems	Internet, email, EDI, ERP	• Enable precise and accurate information flow • Enable faster and cheaper order processing • Reduces uncertainty and improves responsiveness • Enhances flexibility towards customer orders • Improves customer service
Information sharing	The information regarding supply chain operations may be shared among supply chain members to plan and timely schedule various activities of supply chain	Advanced order information, Inventory level, Sales data, Sales forecast, Order status, Production schedule, Capacity and lead time	• Substitute information with inventory and lead time • Reduces the supply chain costs • Reduces the demand variability • Improves the service level • Enhances responsiveness
Joint decision making	The supply chain members may encourage joint decision making to face any future exceptions and to attain a coherent supply chain.	Joint forecasting, joint replenishment and joint ordering resulting in joint profit sharing	• Improves accuracy of forecasting • Increases supply chain profits • Reduces information asymmetries • Improves replenishment process • Reduce inventory level • Improves customer service

Table 5: The description of AHP-fuzzy model

Template 3
Name: AHP-fuzzy model
Objective: Evaluation of coordination considering independent coordination mechanisms
Inputs: Coordination mechanisms, linguistic terms and the relative weights of coordination mechanisms
Brief description: The implementation of coordination mechanisms may be different for different organizations. The selected coordination mechanisms are lying different domains but they are required to coordinate supply chain. The benefits out of using coordination mechanisms may vary as per the importance given to each coordination mechanism. The model is supported by a case study. Since it is easier for managers to give weights for different coordination mechanisms in linguistic terms. The AHP helps to give relative weights and defuzzifying the fuzzy linguistic triangular membership functions with the help of conversion formula, gives an extent of coordination or coordination index.
Outcomes of the model: • An extent of coordination (EC) based on the consideration of four coordination mechanisms. $EC = \omega_{co} CO + \omega_{IT} IT + \omega_{IS} IS + \omega_{JD} JD$ Where, $\omega_{co}, \omega_{IT}, \omega_{IS}$ and ω_{JD} are the relative weights and CO, IT, IS and JD are the composite scores (defuzzyfied) for coordination mechanisms Contracts, Information Technology, Information sharing and Joint Decision-making respectively • The methodology helps to evaluate coordination by giving uniform linguistic terms to different coordination mechanisms and evaluate score based on the performance improvement by all coordination mechanisms.
Linkage to other Templates: Template 2
Reference: Arshinder et al. (2005)

Table 6: Description of Graph-theoretic model

Template 4
Name: Graph-theoretic model
Objective: Evaluation of coordination considering interdependent coordination mechanisms
Inputs: Coordination structures, Qualitative measures for the importance of coordination mechanisms and interdependencies between coordination mechanisms,
Brief description: The graph theoretic approach is used to evaluate the extent of supply chain coordination considering the inheritance of coordination mechanisms and the interdependencies between coordination mechanisms. It is a structural approach consisting of the digraph representation, the matrix representation and the permanent function representation. The coordination structures are defined to represent the inheritance of coordination mechanisms and various kinds of interactions representing interdependencies between coordination mechanisms as per graph theory. The permanent function, a standard matrix function of combinatorial mathematics, gives a quantitative measure of coordination index. The permanent function results in multinomial equation whose every term has physical significance related to the extent of coordination. The terms of permanent function covers all the combinations of interactions between coordination mechanisms. The qualitative measures are used for inheritance of coordination mechanisms and their interdependencies (relative importance of coordination

mechanisms). The permanent function can be developed for all coordination mechanisms at sub-system level by identifying sub-factors affecting coordination mechanisms.

Outcomes of the model:

- A comprehensive measure of supply chain coordination (EC) can be evaluated with the help of graph-theoretic approach.

EC =

$$\underbrace{\prod_{1}^{4} D_i}_{GroupingI} + \underbrace{(0)}_{GroupingII} + \underbrace{\sum_i \sum_j \sum_k \sum_l \left(a_{ij} a_{ji}\right) D_k D_l}_{GroupingIII}$$

$$+ \underbrace{\sum_i \sum_j \sum_k \sum_l \left(a_{ij} a_{jk} a_{ki} + a_{ik} a_{kj} a_{ji}\right) D_l + \sum_i \sum_j \sum_k \sum_l \left(a_{ij} a_{ji}\right)\left(a_{kl} a_{lk}\right)}_{GroupingIV}$$

$$+ \underbrace{\sum_i \sum_j \sum_k \sum_l \left(a_{ij} a_{jk} a_{kl} a_{li} + a_{il} a_{lk} a_{kj} a_{ji}\right)}_{GroupingV}$$

where, a_{ij} represents interdependencies between coordination mechanisms
D_i represents the importance of coordination mechanisms
Grouping I: No interdependency between coordination mechanisms
Grouping II: Self loops (zero because of absence of self loops)
Grouping III: Two-way interactions between coordination mechanisms
Grouping IV: Three-way interaction between coordination mechanisms
Grouping V: Four-way interaction between coordination mechanisms

- The methodology can consider various systems and sub-systems to present an in-depth study of supply chain coordination

Linkage to other Templates: Template 2 and Template 7

Reference: Kaur et al. (2006)

Table 7: Description of Analytical model

Template 5
Name: Analytical model
Objective: The impact of coordination mechanisms on the performance measures and determine the decision variables of coordination mechanisms coherently and mutually
Inputs: Newsboy model, Profit function of all supply chain members, contract parameters and coordination elements
Brief description: An analytical model is an extension of newsboy model (where supply chain member takes the decision individually or local). The coordination elements like interdependency, coherency and mutuality in conjunction with supply chain contracts may help to control coordination by developing relationship between coordination mechanisms and performance measures. The decision variables of coordination mechanisms are selected in the best interest of supply chain members. The supply chain members are interdependent for quantity, information and money. The coherent decision-making helps to determine a common agreeable order quantity throughout supply chain. In conjunction with coherency coordination mechanisms; supply chain contracts are introduced so that all supply chain members can realize mutual

benefits. The difference between the case of newsboy model (no coordination) and the coordination cases with coherency and mutuality may help in realizing the importance of supply chain coordination.
Outcomes of the model: • An analytical model presented forms relationship between coordination mechanisms and various performance measures such as: Revenues realized, salvage value realized, goodwill cost incurred, marginal cost incurred and wholesale value realized • Given the profit functions of all members in case of no coordination, the inequalities for decision variables of contracts can be written such as the decision is coherent and mutually beneficial to all members of supply chain.
Linkage to other Templates: Template 6 and Template 7
Reference: Arshinder et al. (2007)

Table 8: Description of simulation approach

Template 6
Name: Simulation of Analytical model
Objective: Generation of 'what-if' scenarios to realize the importance of coordination
Inputs: Contract parameters data, profit function of all supply chain members, mutually beneficial constraints
Brief description: The simulation is very useful tool to generate and compare different scenarios of supply chain contracts discussed in analytical model. The simulation helps in quantifying the different performance measures by using the profits functions of analytical model as input. The 'what-if' scenarios in simulation will also help supply chain members to decide under what conditions the contracts will coordinate members prior to the actual activities happen. These scenarios may also guide that by using which kind of input data will coordinate and which are the values there are no feasible decision variables for supply chain contracts. The simulation also presents new performance measures like price flexibility and quantity flexibility provided to the supply chain members by designing various kinds of contracts.
Outcomes of the model: • The simulation helps in generating various what-if scenarios of coordination by supply chain contracts, which may act as decision-making tool for future planning. • It helps to quantify various performance measures and also introduce new performance measures like flexibility.
Linkage to other Templates: Template 5 and Template 7
Reference: Arshinder et al. (2006 (b))

Table 9: Model to assess coordinated supply chain

Template 7
Name: Assessment of coordinated supply chain
Objective: To assess the overall effect of performance measures of coordinated supply chain
Inputs: Performance measures from simulation, graph theoretic model
Brief description: The performance improvement resulted from different scenarios of simulation may be used to quantify coordination between supply chain members. The performance measures can be represented by structure and graph theoretic model can be applied to evaluated overall

index of supply chain coordination. The performance measures improved after using coordination mechanisms are indicators of value of coordination. The various performance measures can be consolidated with the digraph representation, matrix representation and permanent function of performance measures for each supply chain members. The consolidated value of consolidated performance measures for different members may form new structures of supply chain coordination. Again by applying graph-theoretic model in the structure of supply chain coordination gives an overall extent of supply chain coordination or supply chain coordination index (SCCI).

Outcomes of the model:

An overall extent of supply chain coordination is evaluated based on the consolidated performance measures of all supply chain members.

SCCI =

$$\underbrace{\prod_{1}^{4} P_i}_{\text{GroupingI}} + \underbrace{(0)}_{\text{GroupingII}} + \underbrace{\sum_i \sum_j \sum_k \sum_l \left(a_{ij} a_{ji}\right) P_k P_l}_{\text{GroupingII\_I}}$$

$$+ \underbrace{\sum_i \sum_j \sum_k \sum_l \left(a_{ij} a_{jk} a_{ki} + a_{ik} a_{kj} a_{ji}\right) P_l + \sum_i \sum_j \sum_k \sum_l \left(a_{ij} a_{ji}\right)\left(a_{kl} a_{lk}\right)}_{\text{GroupingIV}}$$

$$+ \underbrace{\sum_i \sum_j \sum_k \sum_l \left(a_{ij} a_{jk} a_{kl} a_{li} + a_{il} a_{lk} a_{kj} a_{ji}\right)}_{\text{GroupingV}}$$

where, a_{ij} represents the relative importance of performance measures P_i. The above formula is example of evaluating SCCI when there are four Performance measures (i = 4).

Grouping I: No interdependency between performance measures

Grouping II: Self loops (zero because of absence of self loops)

Grouping III: Two-way interactions of performance measures

Grouping IV: Three-way interaction of performance measures

Grouping V: Four-way interaction of performance measures

The performance measures can be quantified by using simulation for all supply chain members. The model first determines the consolidated performance measure for all members then again same model can be applied for consolidated performance measures of all supply chain members to evaluate overall SCCI

Linkage to other Templates: Template 4, Template 5 and Template 6

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