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Developing Indian grain supply chain cost model: a system dynamics approach

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Abstract

Purpose – The objective of the present study is to model the total supply chain cost (TSCC) of an Indian grain chain in order to understand and predict the future outcome of each supply chain model in different situations and to devise policies accordingly to reduce TSCC.

Design/methodology/approach – The system dynamics (SD) approach is used to model the TSCC model of an Indian grain chain, which takes care of the dynamic interaction of the cost variables.

Findings – The major findings of the paper are the reduced cost ratios in the different scenarios. A total of nine scenarios are evaluated, which are the cooperative model, contract farming and a collaborative supply chain based on optimistic, pessimistic and most likely views.

Practical implications – The practical implications are the action plans suggested to reduce TSCC in each of the future scenarios of the supply chain model that are developed in the paper.

Originality/value – The TSCC model is beneficial not only for organizations entering into the food business, but also for economic policy makers.

Keywords Supply chain management, Dynamics, Food crops, India

Paper type Research paper

Introduction

The agriculture sector in India accounts for about 25 percent of gross domestic product (GDP) and employs close to 70 percent of the country's work force. However, it is plagued by multitude of problems which hinder its efficient operation. India has seen rapid developments in several areas, most notably in manufacturing industry and the service sector (e.g. information technology). But, in the agriculture sector, the grain supply chain has remain unchanged: over 90 percent of food is sold in unorganised markets, with organised business accounting for just 2 percent of the market (Economic Times Intelligence Group, 2003). According to the Indian Ministry of Trade and Industry, approximately 20 percent of food produced in India is wasted (see www.etfoodprocessing.com). Various research studies by the Economic Times Intelligence Group (ETIG) and the Investment Information and Credit Rating Agency (ICRA) have detailed the weaknesses and problems present in the Indian grain chain (Investment Information and Credit Rating Agency, 2001). First, tonnes of grain are wasted due to improper handling and storage, pest infestation, poor logistics, inadequate storage and transportation infrastructure. Second, intermediaries take large portions of the earnings which should go to farmers. Third, post-harvest losses are about 25-30 percent in India. Even marginal reductions in these losses are bound to bring great relief on the food security front as well as improve the income level of the farmers. Fourth, Indian consumers pay three to four times the farm gate price, as compared to

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developed countries where the consumer pays one and a half to two times the farm gate price. Also, 60-80 percent of the price that consumers pay goes to traders, commission agents, traders, wholesalers and retailers (Economic Times Intelligence Group, 2003). These intermediaries (also called commission agents) lead to poor coordination and collaboration in the supply chain, which in turn leads to inefficient information flow.

Seeing the inefficiencies in the Indian grain chain and the opportunity of making good profits, some private and public sector companies entered into this organised food business. These companies were based on three types of model:

(1) the cooperative supply chain model;

(2) the collaborative supply chain model; and

(3) contract farming.

Companies are adopting these models to reduce the total supply chain cost (TSCC) and pass on these saving to consumers in the form of lower prices. However, these companies should understand that these models should be implemented effectively through proper planning: only then will they be able to reduce costs, and without effective implementation through proper planning, the effects on the organisations could be hugely detrimental. Therefore, it is very important for the survival and growth of the organisations that they understand the future scenario of the model which they are adopting or will adopt in the future. Each of the three supply chain models requires a different action plan, and the cost reductions are also different. The present study models the total supply chain cost (TSCC) of the Indian grain chain. The purpose of modeling TSCC is to understand and predict the future outcome of each market scenario and to derive policies accordingly to minimise TSCC. The system dynamics approach is used to model the TSCC. The cost ratio of consumer's cost to farmer's cost (3.44 in Figure 1) indicates poor performance in the Indian grain chain as compared to developed countries.

In this paper we have tried to reduce this cost ratio, and by doing that we improve the performance of the grain supply chain. There are many publications that have addressed performance measurement, measures and metrics in the context of supply chains (Chan *et al.*, 2003; Beamon, 1999; Gunasekaran *et al.*, 2001; Morgan, 2004). Measuring performance in a micro context, Sharma *et al.* (2004) used the system dynamics approach to gauge the performance of one channel member (distributor) in the supply chain and also developed the performance index. However, the present paper is at the macro level and takes into account the whole supply chain.

The paper is further divided into five sections. The first section explains the Indian grain chain, the second section presents the objective of the study, and the third section explains the system dynamics methodology for developing a causal loop diagram and details of SD modeling and flow diagram equations for the auto sector. The fourth

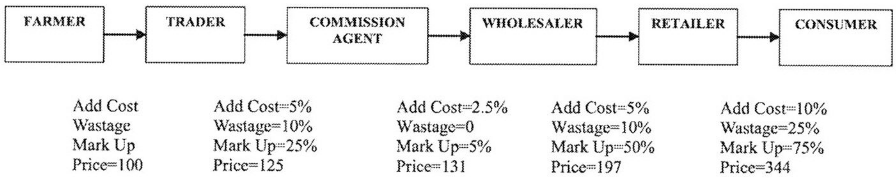

Figure 1.
Estimated cost escalation in the Indian grain chain

Source: Investment Information and Credit Rating Agency (2001) section presents the scenarios of the Indian grain chain, and the paper ends with a discussion and conclusions.

Indian grain supply chain

A supply chain has been described as a system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together via the feed-forward flow of materials and the feedback flow of information (Stevens, 1989). Recently there has been a shift of focus in supply chain management towards a more integrated approach (Towill, 1996). Integrated supply chain management is a process-oriented, integrated approach to procuring, producing, and delivering products and services to customers. Integrated supply chain management covers the management of materials, information, and fund flows (Metz, 1998).

In India wholesalers buy grain from the Agriculture Produce Marketing Committee (APMC), which is established in every state or in every major producing region by the Government. The APMC is meant to consolidate buyers and sellers in a central place to reduce time, effort and cost. In the APMC there are traders who are surrounded by commission agents on all sides. These commission agents deal with farmers and wholesalers on behalf of traders. These commission agents deal with consolidators (who represent the small farmer) on the farmer's side and wholesalers on the retailer's side (Table I). These consolidators and commission agents charge their fees as a percentage of the transaction. This number of people varies across the markets, and their percentages also vary. In this study we have considered five major players in the Indian grain chain:

(1) farmers;

(2) traders;

(3) commission agents;

(4) wholesalers; and

(5) retailers (also considered in the ICRA report).

Table I. Intermediaries in the grain supply chain and their margins and value additions

Intermediary in Indian grain chain	Margin added (per cent)	Principal value added	Comparable American intermediary
Small farmer	N/A	Production	Large farmer, cooperatives
Consolidator	10-15	Aggregation at village level	Wholesaler
Commission agent	10-15	Negotiating and demand supply matching	Wholesaler
Trader	10-15	Consolidation at district (AMPC) level	Wholesaler
Commission agent	10-15	Larger scale demand supply matching	Wholesaler
Wholesaler	25-30	Consolidation and reselling transaction to retailers	Wholesaler
Retailer	25-30	Sells to consumers	Retailer
Number of intermediaries	7-8		3-4

Source: Economic Times Intelligence Group (2003)

Figure 1 clearly reflects that if the farmer sells grain at 100 rupees then by the time it reaches the trader its price becomes 125. Then the commission agent further adds to it and the price rises to 131. Then the wholesaler increases the price by 50 percent, and it rises to 197. The wholesaler adds no value to the grain, except that he breaks them into small parts. Finally the retailer adds his own cost and the final cost rises to 344. The end consumer on average pays more than three times the farm gate price for grain. The additional cost, wastage and mark-up of these participants (trader, commission agent, and wholesaler) drastically increase the cost, by up to almost 3.5 times. The data in Figure 1 clearly show the effect that the number of participants has on the price for both farmers and consumers. Table I presents the Indian intermediaries and comparable American intermediaries along with the margins and value additions made by them.

Some of the reasons for the existence of these intermediaries in the grain supply chain are:

- age-old historical loyalty of farmers to their agents, because these agents provide debt to the farmer;
- local understanding and relationships with transporters;
- lethargy on the part of government and NGOs to educate farmers regarding other options;
- lack of guidelines and rules in the development and supply of produce staples;
- organised cartels between commission agents, wholesalers and transporters;
- lack of scale in terms of what each farmer produces, sheer numbers of small farmers drive down bargaining power; and
- lack of effort in development from front-end players (retailers) and institutions.

Objective

The objective of the present study is to model the total supply chain cost (TSCC) of the Indian grain chain. The purpose of modeling TSCC is to understand and predict the future outcome of each market scenario and to devise policies accordingly to minimise TSCC. Each of the nine scenarios suggests improvement in the performance of the supply chain by decreasing the cost ratio. The paper presents nine scenarios for the cooperative model, contract farming and collaborative supply chain based on optimistic, pessimistic and most likely situations.

System dynamics methodology

The system dynamics (SD) approach is used to model the TSCC. The application of system dynamics modeling to supply chain management has its roots in industrial dynamics (Forrester, 1958, 1961). SD is a methodology for understanding the behavior of complex, dynamic social-technological-economic-political (STEP) systems to show how system structures and the policies used in decision making govern the behavior of the system. SD focuses on the structure and behavior of systems composed of interacting feedback loops. The objective of the SD approach is to capture the dynamic interaction of different system variables and to analyze their impact on policy decisions over a long-term horizon.

Procedural steps in system dynamics modeling

The objective of the SD study is to attain some desired goals through modifications of the system. For this, a system boundary is defined and a model of the system is built. The systematic procedural steps in SD modeling are as follows (Roberts, 1978):

(1) define the problems to be solved and goals to be achieved;

(2) describe the system with a causal loop/influence diagram;

(3) formulate the structure of the model (i.e. develop the flow diagram for systematizing symbols, arrow designator and the format of system dynamic modeling in the form of DYNAMO equations);

(4) collect the initial data/base data needed for model operation either from historical data and/or from discussion with executives/planners who have knowledge and experience of the system under study – these are the initial value of all the level variables, constants and policy data;

(5) validate the model on some suitable criteria to establish sufficient confidence in the model; and

(6) use the model to test various policy actions to find the best way to achieve prescribed goals.

SD procedural steps as explained above were used in developing the SD model for the Indian grain chain.

System dynamics model of the grain supply chain cost

Morecroft (1988) emphasized that model conceptualization begins with causal loops and moves to rate/level flow diagrams and finally to explicit equations capturing the diagram structure. Thus, the objective of the SD model is to capture the dynamic interaction of different variables that the system has and to analyze the policy decision over a long-term time horizon. Causal loop diagramming is an important tool, which helps the modeler to conceptualize the real world system in terms of feedback loops. It is very important to identify the key variables of TSCC before developing a causal loop diagram for the Indian grain chain. To model the grain chain, we consider Figure 1. The major cost components of the grain supply chain are the farmer's price, additional costs, wastage and mark-ups.

Farmer's price

The farmer's price (FP) is the starting point of the grain supply chain. This price contains the cost of growing and processing the grain at farmer's end and margins of the farmers. The farmer's price has a proportional effect on the supply chain cost. These costs are affected by the total farm production (TFP), yield per hectare (YPH) of land and cost of inputs (COI).

Wastage

Total wastage (TW) may be due to three reasons:

(1) obsolesce losses (OL);

(2) transit losses (TL); and

(3) pilferage losses (PL).

This wastage depends on the number of intermediaries in the chain. Wastage has a proportional effect on the supply chain cost. This wastage depends on how many times the grain is handled or transported in the chain, so wastage also depends on the number of intermediaries.

Additional costs

Nearly all channel members incur additional costs, which can be divided into five elements:

(1) inventory holding costs (IHC);

(2) materials handling costs (MHC);

(3) transportation costs (TC);

(4) order processing costs (OPC); and

(5) packaging costs (PC).

We have divided these costs based on discussions with traders, practitioners and supply chain experts. But there can be variations among the members in the compositions of costs. For example, in the case of commission agents the major area of additional costs is covered by components such as materials handling costs and order processing costs (Figure 2). The total additional cost is denoted "TAC".

Mark-up

Mark-up is an amount added to the cost price to determine the selling price. Each participant in the chain has their own mark-up percentage, and this is one of the main reasons for price escalation. The greater the number of participants (NOP) in the chain, the more the times a margin is taken by them, and that increases the supply chain cost. Total mark-up (TMA) depends on the number of the participants and the profit per participant (PPP).

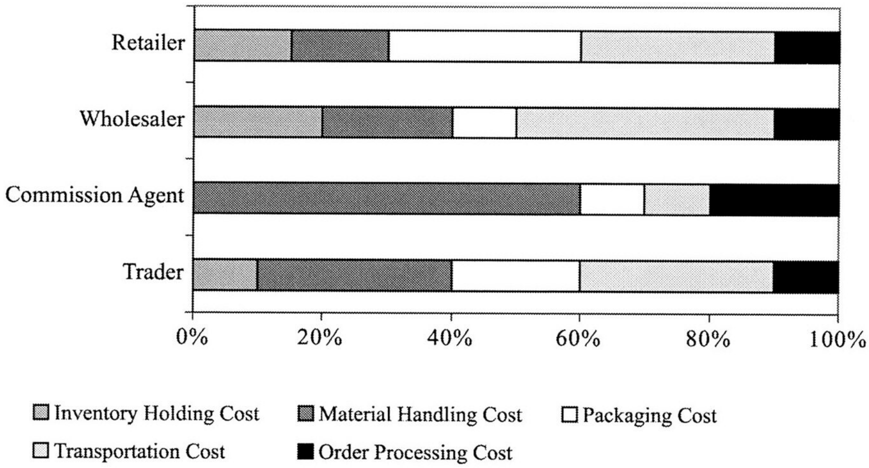

Figure 2.
Elements of additional cost

Causal loop diagram

An integrated causal loop diagram of this model reflecting the interactions of the above variables was developed, and is shown in Figure 3. The causal loop diagram is an important tool which helps the modeler to conceptualize the real-world system in terms of feedback loops. In a causal loop diagram, the arrows indicate the direction of influence, and the plus or minus sign the type of influence. All other things being equal, if a change in one variable generates a change in the same direction in the second variable, relative to its prior value, the relationship between the two variables is referred to as positive. If the change in the second variable takes place in the opposite direction, the relationship is negative. Causal loop diagrams characterize the initial view of the system and basically serve the purpose of communication between the modeler and the policy maker. However, the formulation of an operational model of the system is based on more specific structural details, like rates or policy variables, accumulation of level, auxiliaries, constants, information flows and delays.

In the causal diagram of total supply chain cost there are ten negative feedback loops. Four of them are between the supply chain cost and the total additional cost, total wastage, total mark-up and farmer's price, which means that an increase in any one of these costs will increase the total supply chain cost. When the supply chain cost increases, people try to reduce the one of these costs. For example, many farmers have now started selling direct to the retailer, bypassing traders, commission agents and wholesalers. In this way they both are sharing the mark-up and the other costs that these participants make. In some cases retailers are also integrating backwards and removing one or two participants in the chain and increasing their margins or providing more value to customers.

The other five negative loops are between the total additional cost and the inventory holding cost, the transportation cost, the materials handling cost, the packaging cost

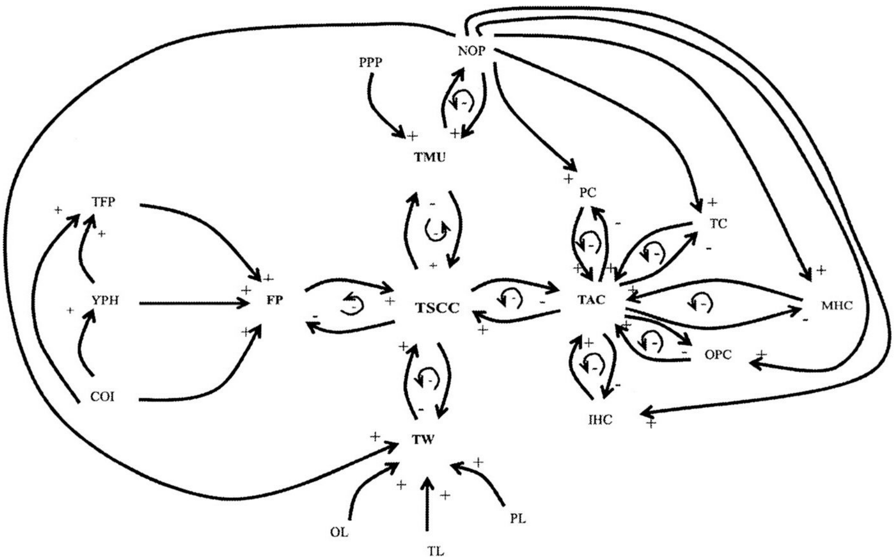

Figure 3.
Causal diagram of total supply chain cost

and the order processing cost. Increasing any one of these costs will lead to increases in additional costs. When additional costs increase, then channel members try to reduce these costs. Transportation costs are usually reduced by transporting the material in bulk, and channel members attempt to reduce costs per kg in this way. In the case of order processing, in some places channel participants have started using computers and information technology. Using standard packaging material throughout the chain also reduces packaging costs.

One of the most important variables in the causal diagram is the number of participants (NOP). This increases the total supply chain cost in a number of ways. It can easily be seen what role the number of participants (NOP) plays in the grain supply chain in India. The NOP also includes "intermediaries" or "middlemen" in the grain chain. The formulation of an operational model of the TSCC system is based on specific structural details, like rates or policy variables, accumulation of levels, auxiliaries, constants, information flows and delays. Flow diagrams represent such details and specific aspects of the model structure (Richardson and Pugh, 1981).

Flow diagram

The causal loop for the TSCC model has been converted into a flow diagram with the help of ithink 7.0.2 ANALYST software (Richmond, 2001). Level variables, rate variables, decision factors and decision points are inter-connected. The SD equations have been generated in the model, and represents the dynamics of the systems encapsulating the rate of changes with complex interactions.

Model for TSCC

We determined the total supply chain cost (TSCC) in two ways (Figure 4):

(1) by addition of the farmer's price (FP), trader's cost (TC), commission agent's cost (CC), wholesaler's cost (WC) and retailer's cost (RC); and

(2) total supply chain cost is computed function-wise (TSCCF) by the addition of farmer's price (FP), total additional cost (TADC), total mark-up (TMA) and total wastage (TW).

For illustration purposes, a few representations of associated SD equations are now discussed.

Here, *A* denotes auxiliary equations and *K* denotes the system state at a time *K*. For example, the first equation in the following set implies that the TSCC at time *K* is the sum of the farmer's price, the trader's cost, the commission agent's cost, the wholesaler's cost and the retailer's cost at time *K*. The equations are written in terms of the generalized time steps *J*, *K* and *L* using the arbitrary convention that *K* represents the "present" point in time at which the equations are being evaluated. In other words, we assume that the progress of the solution has just reached time *K*, but that the equations have not yet been solved for levels at time *K*, or for rates over the interval *KL*. The level equations show how to obtain levels at time *K*, based on levels at time *J*, and on rates over the interval *JK*. At the time *K*, when the level equations are evaluated, all necessary information is available and has been carried forward from the preceding time step. The rate equations are evaluated at the present time *K* after the level equations have been evaluated. The values determined by the rate (decision) equations determine the rates that represent the actions that will be taken over the forthcoming

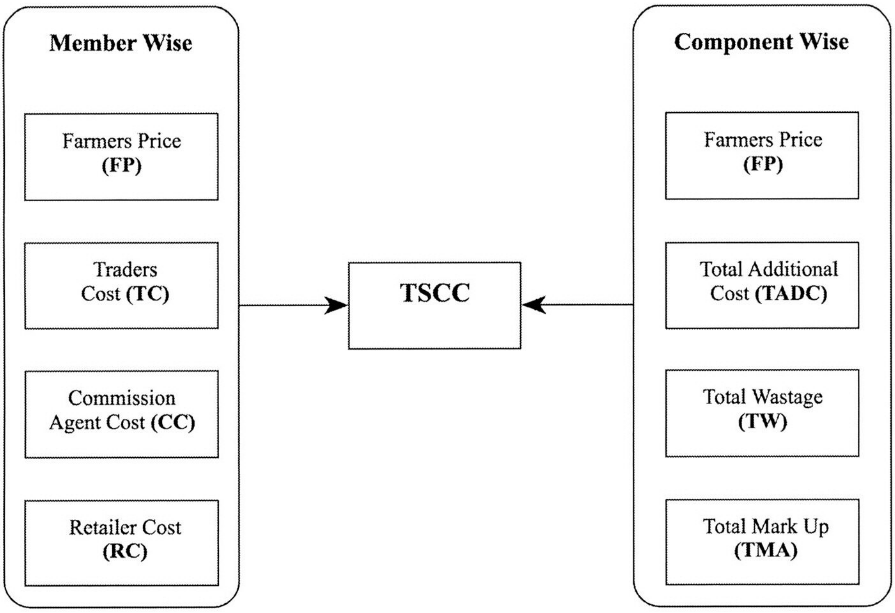

Figure 4. Components of total supply chain cost (TSCC)

interval *KL*. Constant rates imply a constant rate of change in levels during a time interval.

After evaluation of the levels at time *K* and the rates for the interval *KL*, time is "indexed". That is, the *J*, *K*, *L* positions are moved one time interval to the right. The *K* levels just calculated are re-labeled as *J* levels. The *KL* rates become the *JK* rates. Time *K*, "the present", is thus advanced by one interval of time of *DT* length. The entire computation sequence can then be repeated to obtain a new state of the system at a time that is one *DT* later than the previous state. By definition this *DT* interval must be short enough so that it represents constant rates of flow over the interval as a satisfactory approximation to continuously varying rates in the actual system.

Total supply chain cost (TSCC) is an auxiliary variable which is determined by the addition of the farmer's sales value (FP), the trader's cost (TC), the commission agent's cost (CC), the wholesaler's cost (WC) and the retailer's cost (RC). Total supply chain cost function-wise (TSCCF) is an auxiliary variable, which is determined by the addition of farmer's sales value (FP), total additional cost (TADC), total mark-up (TMA) and total wastage (TW).

Additional cost can be also calculated in two ways, i.e. functional-wise and channel member-wise. Channel member-wise, total additional cost (TAC) is an auxiliary variable which is determined by summation of the additional cost of the trader (ACT), the additional cost of the commission agent (ACC), the additional cost of the wholesaler (ACW) and the additional cost of retailer (ACR). Functional-wise, total additional cost (TADC) is an auxiliary variable which is determined by summation of the total inventory holding cost (TIHC), the total materials handling cost (TMHC), the total transportation cost (TOTC), the total order processing cost (TOPC) and the total packaging cost (TPC). Elements of additional cost (i.e. TIHC, TMHC, TOTC, TOPC and TPC) are determined from participant: for example, the total inventory holding cost (TIHC) is determined by the inventory holding cost of the trader, the commission agent, the wholesaler and the retailer. Similarly, total wastage (TW) and total mark-up (TMA) are calculated:

$$A\ \mathrm{TSCC}.K = \mathrm{FP}.K + \mathrm{TC}.K + \mathrm{CC}.K + \mathrm{WC}.K + \mathrm{RC}.K,$$

$$A\ \mathrm{TSCCF}.K = \mathrm{TADC}.K + \mathrm{TMA}.K + \mathrm{FP}.K + \mathrm{TW}.K,$$

$$A\ \mathrm{TAC}.K = \mathrm{ACT}.K + \mathrm{ACC}.K + \mathrm{ACW}.K + \mathrm{ACR}.K,$$

$$A\ \mathrm{TADC}.K = \mathrm{TIHC}.K + \mathrm{TMHC}.K + \mathrm{TOTC}.K + \mathrm{TOPC}.K + \mathrm{TPC}.K,$$

$$A\ \mathrm{TIHC}.K = \mathrm{IHCT}.K + \mathrm{IHCC}.K + \mathrm{IHCW}.K + \mathrm{IHCR}.K,$$

$$A\ \mathrm{TMHC}.K = \mathrm{MHCT}.K + \mathrm{MHCC}.K + \mathrm{MHCW}.K + \mathrm{MHCR}.K,$$

$$A\ \mathrm{TOTC}.K = \mathrm{TCT}.K + \mathrm{TRCC}.K + \mathrm{TCW}.K + \mathrm{TCR}.K,$$

$$A\ \mathrm{TOPC}.K = \mathrm{OPCT}.K + \mathrm{OPCC}.K + \mathrm{OPCW}.K + \mathrm{OPCR}.K,$$

$$A\ \mathrm{TPC}.K = \mathrm{PCT}.K + \mathrm{PCC}.K + \mathrm{PCW}.K + \mathrm{PCR}.K,$$

$$A\ \mathrm{TW}.K = \mathrm{WR}.K + \mathrm{WW}.K + \mathrm{WCA}.K + \mathrm{WT}.K,$$

$$A\ \mathrm{TMA}.K = \mathrm{MUT}.K + \mathrm{MUC}.K + \mathrm{MUW}.K + \mathrm{MUR}.K,$$

where TSCC is the total supply chain cost (in rupees), TSCCF is the total supply chain cost function-wise, FP is the farmer's price (in rupees), TC is the trader's cost (in rupees), CC is the commission agent's cost (in rupees), WC is the wholesaler's cost (in rupees), RC is the retailer's cost (in rupees), TW is total wastage, TMA is the total mark up, TAC is the total additional cost, TADC is the total add cost, TIHC is the total inventory holding cost, TMHC is the total materials handling cost, TOTC is the total transportation cost, TOPC is the total order processing cost, and TPC is the total packaging cost.

Farmer's cost

The time interval taken in the model is one year and the level variables are the cost at the farmer's end and the wheat production volume. The rate is taken on the basis of the past ten years of available data for wheat production and cost. Wheat production is increasing at a rate (GPM) of 2.5 percent and the cost of production is increasing at a rate (PIM) of 8 percent. The quantity of grain produced (QG) and the cost of production (COI) in 2001 were taken:

$$A\,\mathrm{FP}.K = \mathrm{QG}.K^{*}\mathrm{COI}.K,$$

$$L\,\mathrm{QG}.K = \mathrm{QG}.J + (DT)(\mathrm{RIQG}.JK),$$

$$N\,\mathrm{QG} = 6.85\mathrm{e}8,$$

$$R\,\mathrm{RIQG}.KL = \mathrm{QG}.K^{*}\mathrm{GPM}$$

$$C\,\mathrm{GPM} = 0.025,$$

$$L\,\mathrm{COI}.K = \mathrm{COI}.J + (DT)(\mathrm{PI}.JK)$$

$$N\,\mathrm{COI} = 497.9,$$

$$R\,\mathrm{PI}.KL = \mathrm{COI}.K^{*}\mathrm{PIM},$$

$$C\,\mathrm{PIM} = 0.08,$$

where QG is the quantity required (quintals), FP is the farmer's price (in rupees), COI is the cost of inputs (in rupees/quintal), PI is the price increase, and PIM is the price increment multiplier (fraction).

Trader's cost

The trader's cost is a summation of all the costs that the trader incurs. They are the additional costs of the trader, the total wastage of trader and the mark-up of the trader. The total trader's cost (TTC) is an auxiliary variable which is a summation of the additional cost of trader (ACT), the wastage of the trader (WT) and the mark-up of the trader (MUT). The additional cost of the trader (ACT) is an auxiliary variable which is a summation of the inventory holding cost (IHCT), the materials handling cost (MHCT), the transportation cost (TCT), the order processing cost (OPCT) and the packaging cost (PCT) of the trader. These elements are the product of the farmer's price and the percentage of these components (Figure 3). The wastage of the trader (WT) is an auxiliary variable which is a product of the farmer's price and the percentage of wastage of the trader (PWT). The percentage of wastage of the trader is a constant and is taken as being 10 percent. Mark-up by trader (MUT) is an auxiliary variable which is product of the farmer's price and the percentage of mark-up of the trader (PMUT). The percentage of mark-up of the trader is a constant, and is taken as being 10 percent:

$$A\,\mathrm{TTC}.K = \mathrm{ACT}.K + \mathrm{WT}.K + \mathrm{MUT}.K + \mathrm{FP}.K,$$

$$A\,\mathrm{ACT}.K = \mathrm{IHCT}.K + \mathrm{MHCT}.K + \mathrm{TCT}.K + \mathrm{OPCT}.K + \mathrm{PCT}.K,$$

$$A\,\mathrm{IHCT}.K = \mathrm{FP}.K^{*}\mathrm{PIHCT},$$

$$C\,\text{PIHCT} = 0.005,$$

$$A\,\text{MHCT}.K = \text{FP}.K^{*}\text{PMHCT},$$

$$C\,\text{PMHCT} = 0.015,$$

$$A\,\text{TCT}.K = \text{FP}.K^{*}\text{PTCT},$$

$$C\,\text{PTCT} = 0.015,$$

$$A\,\text{OPCT}.K = \text{FP}.K^{*}\text{POPCT},$$

$$C\,\text{POPCT} = 0.005,$$

$$A\,\text{PCT}.K = \text{FP}.K^{*}\text{PPCT},$$

$$C\,\text{PPCT} = 0.01,$$

$$A\,\text{WT}.K = \text{FP}.K^{*}\text{PWT},$$

$$C\,\text{PWT} = 0.10,$$

$$A\,\text{MUT}.K = \text{FP}.K^{*}\text{PMUT},$$

$$C\,\text{PMUT} = 0.10,$$

$$A\,\text{TC}.K = \text{TTC}.K - \text{FP}.K,$$

where TTC is the total trader's cost (in rupees), ACT is the additional cost for the trader (in rupees), WT is the wastage for the trader (in rupees), MUT is the mark-up by the trader (in rupees), IHCT is the inventory holding cost of the trader, MHCT is the materials handling cost of the trader, TCT is the transportation cost of the trader, OPCT is the order processing cost of the trader, TC is the trader's cost, PCT is the packaging cost of the trader, PIHCT is the percentage inventory holding cost of the trader (dimensionless), PMHCT is the percentage materials handling cost of the trader (dimensionless), PTCT is the percentage transportation cost of the trader (dimensionless), POPCT is the percentage order processing cost of the trader (dimensionless), PPCT is the percentage packaging cost of the trader (dimensionless), PWT is the percentage wastage of the trader (dimensionless), and PMUT is the percentage mark-up of the trader (dimensionless).

Similarly, other sets of equations of commission agent, wholesaler and retailer have been developed across the range of factors and interactions that impact on the TSCC and TSCCF. This builds a "model" of the situation that can be used to explore the efficacy of alternative improvement strategies.

Altogether there are 73 variables in the model. For the purposes of validation of the model, three important variables were selected. The three variables selected were the packaging cost, transportation cost and materials handling cost. The packaging cost, transportation cost and materials handling cost per quintal were Rs. 35.35, Rs. 37.55 and Rs. 53, respectively. Then the model was subjected to some statistical tests to lend added credence to the work. This was carried out by deriving the mean and standard deviation of the model and actual values followed by a t-test for two means and an F-test for two variances, as summarised in Table II. The tabulated values of the t-test with 20 degrees of freedom and F test with (10,10) are 2.086 and 2.98 respectively. The calculated values for packaging cost, transportation cost and materials handling cost are within 95 percent confidence limits for the t-tests and F-tests. On the above basis, the model can be considered valid and hence the model can be used for projecting future costs.

Future projection

Future projection of total supply chain cost is done by generating three scenarios (i.e. cooperative models, contract farming and collaborative supply chain). The optimistic, pessimistic and most likely views of the above mentioned three scenarios are considered for analysis. In total, nine scenarios generated. The present simulation model was changed and run nine times – once for each scenario – to get the final results. The three models are explained briefly below.

Cooperative model

The cooperative model of farming is an improvement over individual farming (Figure 5). In the cooperative pattern farmers come together and form a cooperative. In some parts of India milk is collected and sold by cooperatives. The cooperative movement for milk was initiated by the National Dairy Development Board (NDDB) (Chakravarty, 2000). Due to these milk cooperatives, the efficiency, transparency and fairness of the system have improved (see www.digitaldividend.org/pdf/akashganga.pdf). In the case of grain, the domain of cooperative arrangements can range across various activities of the supply chain like procurement, storage, processing and marketing. The government's attitude towards the cooperative system is positive, especially after the success of the milk sector.

As mentioned previously in this paper we take three views – optimistic, pessimistic and most likely – in all three grain supply chain models. In the pessimistic view of the cooperative model we remove the commission agent, mark-up and additional cost. Here we are assuming that the cooperative will at least be able to overcome the commission agent. The variables changed in the model are percentage mark-up of the commission

Variable	Mean Actual	Mean Model	Standard deviation Actual	Standard deviation Model	t-test	F-test
Packaging cost	1.74E + 10	1.70E + 10	5.17E + 09	6.42E + 09	0.1523	0.5065
Transportation cost	2.48E + 10	2.832E + 10	8.21E + 09	9.00E + 09	0.2716	0.7784
Materials handling cost	1.76E + 10	1.759E + 10	5.82E + 09	5.82E + 09	− 0.0045	0.6820

Table II. Validation of model based on comparison of actual and SD model results from 1991 to 2001

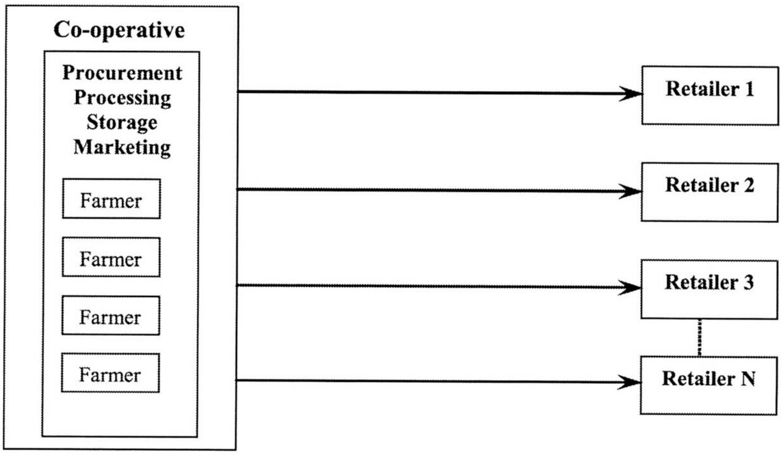

Figure 5.
Co-operative supply chain model

agent (PMUC) and the additional cost of the commission agent (ACC). In the most likely view, we remove the trader's and the commission agent's margins. The variables changed in the model are PMUC and the percentage mark-up of the trader (PMUT). In the optimistic view we removing the trader, commission agent and wholesaler wastage, mark-up and handling cost. The variables changed in the model are PMUC, PMUT, the percentage markup of the wholesaler (PMUW), PMHCT, PWT, percentage materials handling cost of the commission agent (PMHCC), the percentage wastage of the commission agent (PWC), the percentage materials handling cost of the wholesaler (PMHCW) and the percentage wastage of the wholesaler (PWW). The changes were made in the equations of the SD model developed in accordance with each view of the cooperative model, and the results are shown in Figure 6.

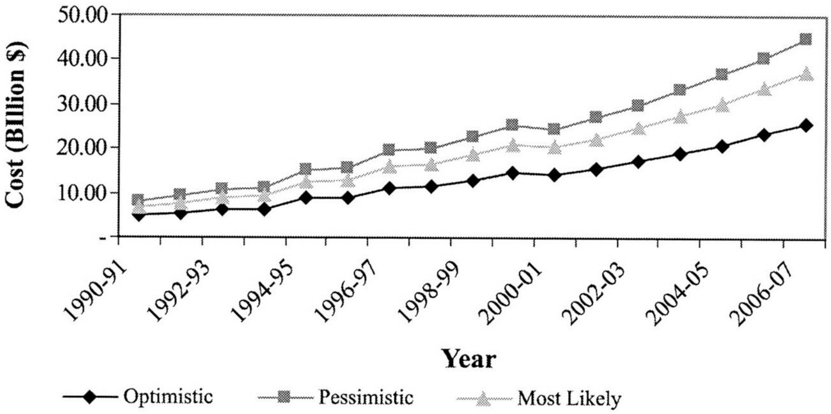

Figure 6.
Total supply chain cost in the cooperative model

Collaborative supply chain
One of the models of the grain supply chain is collaborative (Figure 7). At present every retailer striving for scale and quality is creating distinct and separate supply chains, which are basically the same, i.e. farmer-AMPC-retailer. The collaborative effort already visible in consumer durables and FMCG can also be applied here. In this arrangement the third party manages the system, i.e. he takes the grain from the farmer, consolidates and then perform cross docking for retailers. In essence there are vertical silos which do not allow the scaling up of the grain supply chain. Experts and academics believe that the collaborative effort already visible in consumer durables and FMCG would give the food supply chain exactly the scale and consolidation that it needs to attract more investment, technology and people. This could give the grain supply chain exactly the scale and consolidation that it wants.

In the pessimistic view of the collaborative supply chain model there will be a reduction in the wastage and mark-up of to 25 percent for intermediaries. The variables changed in the model are PMUC, PMUT, percentage mark-up of the wholesaler (PMUW) PWT, percentage wastage of the commission agent (PWC), and the percentage wastage of the wholesaler (PWW). In the most likely view, the wastage and mark-up of the intermediaries are reduced by 50 percent. The variables changed in the model are PMUC, PMUT, PMUW, PWT, PWC and PWW. In the optimistic view we have removed the commission agent and mark-up and wastage are reduced by 50 percent for the other intermediaries. The variables changed in the model are PMUC, PMUT, PMUW, PWT, PWC and PWW. The changes were made in the equations of each model according to each scenario, and the results are shown in Figure 8.

Contract farming
Contract farming is the next option (Figure 9). Farmers under forward contracts can define contract farming as a system for the production and supply of grain with an industrial partner. The contract will include a commitment from the farmer to provide

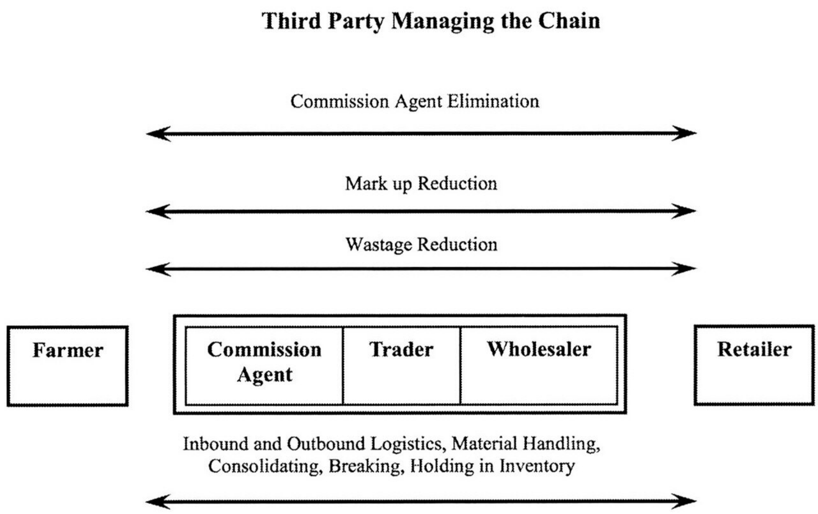

Figure 7. Collaborative supply chain model

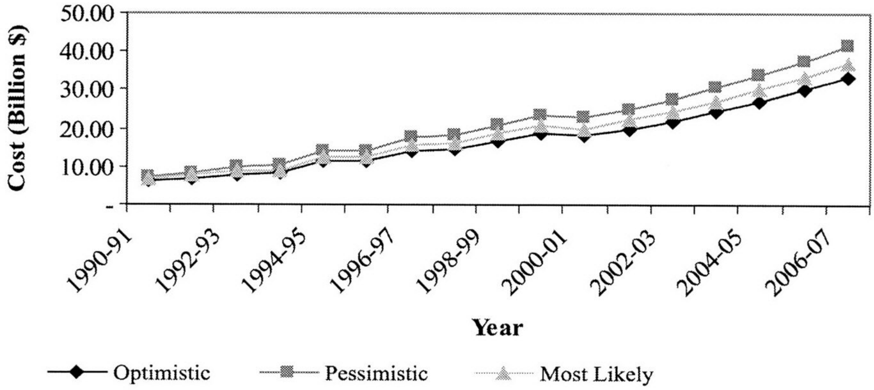

Figure 8.
Total supply chain cost in the collaborative supply chain model

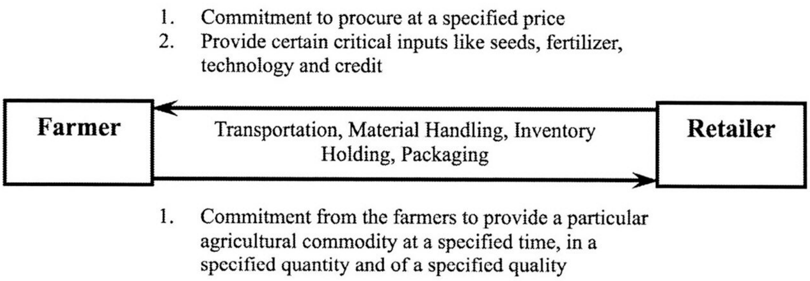

Figure 9.
Contract farming supply chain model

a particular agricultural commodity at a specified time, in a specified quantity and of a specified quality. The purchaser provides a commitment to procure produce at a specified price. Usually the purchaser also agrees to provide certain critical inputs like seeds, fertilizer, technology and credit. This is helpful for farmers, since they get access to the inputs and the market at a fair price. Also, the processor gets an assured supply of raw material.

In the pessimistic view of the contract farming model there will be a reduction in the cost of production of grain and in the mark-up of each participant. The variables changed in the model are PMUT, PMUC, PMUW, percentage mark-up of the retailer (PMUR) and COI. In the most likely view, there will be a reduction in the order processing costs of the trader and the commission agent and a reduction in the wastage of the trader and the commission agent. The variables changed in the model are PMUT, PMUC, PMUW, PMUR, COI, POPCT, percentage order processing cost of the commission agent (POPCC), PWT and PWC. In the optimistic view there will be no mark-up and wastage from intermediaries. Order processing costs of the trader, wholesaler and commission agent and the cost of production will reduce. The variables changed in the model are PMUT, PMUC, PMUW, PMUR, COI, POPCT, POPCC, percentage order processing cost of wholesaler (POPCW), PWT, PWC, PWW. The changes were made in the equations of each model according to each scenario and the results are shown in Figure 10.

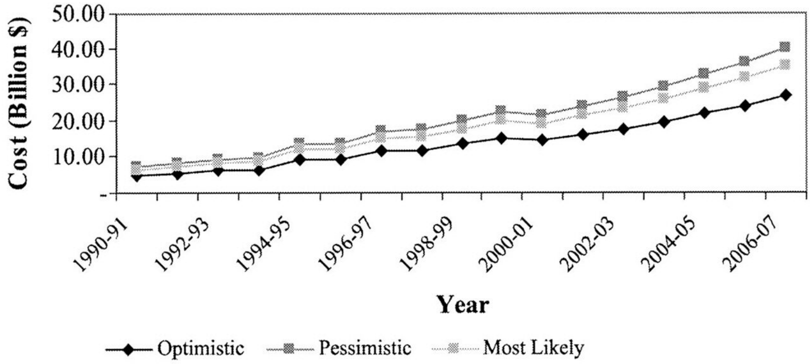

Figure 10. Total supply chain cost in the contract farming model

Discussion and conclusion

As compared to developed countries, the Indian grain supply chain is more complex and difficult to manage because of an unorganised grain market, price escalation and large number of intermediaries. In order to manage the grain supply chain, the Indian Government established APMC. APMC acts as a marketing exchange where traders purchase grain from farmers and sell it to wholesalers or retailers. But due to poor connectivity of villages, small land holding size and low education levels of farmers, commission agents (intermediaries) appear in the chain. With time these intermediaries have become powerful and have formed cartels. These cartels become counter-productive for the farmers who are left with no choice but have to sell their grain through these commission agents. Similarly, wholesalers or retailers have to purchase through these commission agents. This disruption in the selling and buying process leads to price escalation and high transaction costs (three to four times the actual price). Coase (1937) observed that under this condition, the cost of conducting economic exchange in a market may exceed the cost of organising the exchange within a firm. In order to manage the high transaction cost, a great deal of cooperation and collaboration is required in the grain supply chain.

The purpose of this paper was to develop different models (cooperative model, contract farming model and collaborative model) to minimise the total supply chain cost (TSCC) under different scenarios – optimistic, most likely and pessimistic – to devise policies accordingly. This paper has proposed nine scenarios which may help in managing total supply chain cost. As discussed in the nine scenarios, we have proposed to reduce some of the intermediaries in the three suggested models of the grain supply chain. The results of the cost ratios of all nine scenarios are summarized in Table III. The optimistic scenario in cooperative model and in contract farming

Scenario	Optimistic	Pessimistic	Most likely
Cooperative supply chain	1.90	3.31	2.74
Contract farming	1.95	1.90	2.58
Collaborative supply chain	2.44	3.06	2.70

Table III. Cost ratio of the cost at the consumer's end to the cost at the farmer's end seems to be the best option, with a cost ratio of about 1.9, whereas in the most likely situation, contract farming seems to be the better option, followed by the cooperative model and the collaborative supply chain model. However, in the pessimistic view, contract farming seems to be a better option, followed by the cooperative model and the collaborative supply chain model. In all the supply chain models contract farming seems to be the better option. The suggested system dynamics grain supply chain model will help in adopting a supply chain strategy to reduce the supply chain cost.

The SD cost model will help channel members to understand the system's behavior with respect to various cost elements under different market scenarios. Analysis of various elements in the model provides a snapshot of the supply chain cost, and identifies areas for improvement. The cost ratio of the consumer's end to the farmer's end is one of the important performance measures of the grain supply chain. Proposing the action plan of reducing this ratio is a step towards performance improvement in the grain supply chain. The SD model may be useful to take policy decisions arising from the dynamic nature of the system. However, real improvement depends on effective implementation.

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