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POLICY INTERVENTIONS FOR SUPPLY CHAIN PERFORMANCE THROUGH QUALITY AUDITING: THE CASE OF A PACKAGING COMPANY

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ABSTRACT

Supply Chain Performance is a key factor for the success of any organization. In highly competitive world, companies are not competing one another it is their supply chains which compete. In this paper, System dynamics (SD) model is developed to find out the policy interventions for supply chain enhancement through quality auditing. Quality auditing is quality practice that is necessary element in quality certifications and quality programs for assessing the state of quality implementation and a yardstick to measure the supply chain performance within an organization. While identifying the dynamic variables associated with quality auditing and unveiling the underlying feedback structure that influence the supply chain performance; a simulated integrated system dynamics model is formulated. Multiple simulation runs of the model is done to find the changes in the model structure and policies have been designed on the basis of parametric changes and structural changes to enhance the supply chain performance.

System Dynamics is a computer-based approach that is useful for policy design and analysis. It addresses the dynamic issues having feedback notion in social, industrial and economic systems. STELLA, a simulated software, is used in this paper to unveil the underlying symptoms that generate the undesirable behavior pattern.

Experimenting with computer model helps to know deeply insight of the problem and determine the areas which pave the path for policy formulations and policy intervention based on practical industrial exposure and the experiential data.

Keywords: *Supply Chain Performance, Quality Auditing, System Dynamics, Policy Design, Computer Simulation*

1) INTRODUCTION

In highly competitive world, where cut throat competition prevails, price hike and shrinking market shares compel the organizations to keep on harnessing innovative methods in order to improve the organizational performance. In Pakistani companies, quality programs, quality practices and quality initiatives have been designed, implemented and monitored at various point in time to create the influence on company performance of the organization. It happens often that companies either follow the customer pressures for quality programs or take these initiatives as a process improvement tool to take the organizations from level of conformance to the level of performance. Such customer requirements or the behavioral pattern of the competition is a key to start the quality programs without understanding their impact (Tan et al, 1999). Efforts have been made by the knowledge creators in the past to work on the area of quality and establish the linkages between quality practices and organizational performance (Anderson et al.1988, 1995, Flynn & Flynn 2005).

Total Quality Management (TQM) and Supply Chain Management (SCM) both are the emerging management disciplines that reinforce each other for organizational excellence. Supply Chain Quality Management (Rashid & Aslam, 2012) is the new term coined with the blend of key ingredients of these two management disciplines to ensure the quality supplies for all supply chain stakeholders. Quality auditing, is a best-proven practice that exists in different quality programs and quality certifications and can contribute for supply chain excellence of the organization. Policy interventions are required either on parametric based or structure based to the sub-variables of the quality auditing to improve the supply chain performance. Auditing skills, effective documentation and auditor productivity can increase the supply chain performance; now there is a management decision to invest in those areas where policy intervention suits to their organizations. There is a dire need to boost the company supply chain excellence while formulating the new policies and intervening the existing ones.

Quality certifications designed and issued by the International Organization for Standardization (ISO) based on Geneva and Quality Programs like 5S, Six Sigma, HACCP, TPM, (Besterfield, 2007) World Class Manufacturing (WCM) all contain variety of quality practices which can contribute for the excellence of the organization. Quality auditing is most commonly used practice in all quality certifications and quality programs (Yusuf, 2008). In literature the impact of quality management practices (Tan et al. 2006) and its linkage between supply chain performance are discussed (Lee et.al, 2007).

Thousands of companies have been certified in Pakistan and hundreds have different quality programs which are using quality auditing as a powerful tool for building the quality culture and to improve the quality system implementation. The purpose of this paper is to understand how quality auditing and its operational framework influence the supply chain performance using feedback structures. How the plausible policies are designed and developed to enhance the supply chain performance (Taylor, 2016) in terms of high order fill rate, perfect order fulfillment, reduced number of customer complaints and reduction in warranty claims / product rejections. This is possible while deploying varied policies and no one can negate the power of qualified auditors who play their role for the process and system improvement. Effective and efficient audit management helps to find the opportunities for improvement for the companies struggling for good to great and become world class champions (Moosa & Shariff 2007).

2) LITERATURE REVIEW

Theory of Total Quality Management and Supply chain management both act as important disciplines to gain the competitive advantage together with strengthening organizational competitiveness (Talib et al. 2011). In past many researchers have taken the pain to make the grouping of several aspects of quality management. Key constructs of total quality management, main areas of theory of quality and critical factors of total quality management have been categorized. Relationships between quality program and organizational performance have been studied (Usman & Raouf, 2009). It has been observed that quality practices act as building blocks to have sustained competitive edge through improved management of networking (Ellinger, 2000). Quality Auditing is the key quality practice that resides in quality certifications and quality programs. Poor audit plans, unskilled auditors, unstructured audit mechanism are the main issues for many companies who are inclined to have certification of Quality Management System ISO 9001 and follow the minimum quality standards (Cellini & Lamantia, 2015). A weakness in the quality auditing practice not only affects the certification process but also hampers the supply chain performance. There is a dire need to address these issues which relate to Quality Auditing in order to enhance the supply chain performance. Using simulation modeling framework, it is important to develop model for designing and exploration of the policies that can overcome these issues and suggest some plausible policies for enhanced supply chain performance. The discipline of industrial dynamics deals with two dimensions one is feedback thought and second is dynamic variables (Towill, 1996) and system dynamics is the most appropriate discipline to address such industrial problems. Supply chain performance, of the focal firm must be linked and interacted with suppliers and customers for problem understanding and problem solution (Saeed, 2014).

2.1) Quality auditing

The name audit gets from the LATIN for a “listener” or “one who listens judicially and attempts cases”. In quality management system, quality auditing can be characterized as a structured, systematic and autonomous approach to decide the consistence between quality activities and related outcomes according to the arranged arrangements and whether these arrangements are implemented successfully and are appropriate to accomplish objectives. Kevin (1996) says in regards to quality Audit “a systematic and autonomous examination to decide if quality activities and related outcomes agree to arranged arrangements and whether these are being implemented and are probably going to accomplish objectives.” Internal auditing is the checking of the quality system by organization staff prepared by certifying body (Kevin, 1996). BSI Training Services (1995) Manual clarifies, “a systematic examination of the expectation, the usage and the viability of chose parts of the Quality System of an association or division.”

3) METHODOLGY

System Dynamics (SD) was developed in the late 1950s at the Massachusetts Institute of Technology (Forrester, 1968). System dynamics focuses on the structure and its behaviour (Sachan et al., 2005). System dynamics often enables top line executives and decision makers to gain insights into the dynamic behaviour of complex systems (Meadows, 1974). While developing the integrated simulated computer model, the modeler requires the know-how of the dynamic variables and feedback notion

(Towill, 1996). This starts with perception of the real-world situation which in turn requires the drawing of model boundaries sufficient to include all the elements which contribute significantly to the problem under study. Industrial dynamics is a powerful modeling tool to study the flow of material, information, and many across these boundaries of dynamic variables (Sweeney & Sterman, 2007). Many people have contributed to the techniques whereby Industrial Dynamics models of real-life systems may be established. System Dynamics is a powerful approach deals with causal complexities (Zakery et al., 2017) and it is a more one of philosophy in which role of management is designing and controlling corporate behaviour by first identifying the symptoms that cause undesirable behaviour and then designing the policies to improve behaviour (Lyneis James M., 1980). The comprehensive definition of Barry Richmond describes the steps of modeling process from conceptual to technical (Richmond, 1993). Usually system dynamics is equally applicable for the complex problems of strategic nature (Strohhecker, 2005). The methodology, however, proved to be valuable and capable of supporting decisions on even short-term scenarios and measures (Strohhecker, 2005).

The model building process involves the following phases highlighted in the paper (Sajjad & Yusuf, 2007).

Sr. No.	Description	Type
Phase 1	Problem Definition Reference Mode Dynamic Hypothesis	Conceptual
Phase 2	System Understanding System Conceptualization Causal Loop Diagram Influence Diagram	Conceptual
Phase 3	Model Representation Structure Diagram Block Diagram Stock and Flow Diagram*	Conceptual
Phase 4	Model Behaviour Equation Writing**	Technical
Phase 5	Model Evaluation and model validity with different tests Computer Simulation Curves	Technical
Phase 6	Policy Design and Policy Analysis Policy Design on the basis of Structural changes Policy Design on the basis of Parametric changes	Technical

*Note: Stock-Flow diagram is developed on the basis of the software used either DYNAMO, STELLA, VENSIM, ITHINK or POWERSIM
**Note: Equation writing for this model is done in STELLA

System dynamics modeling protocol deals with two important dimensions one is to identify the variables that change over period of time and second is feedback notion among the variables (Richardson, 1981). A causal loop that characteristically tends to reinforce or amplify a change in any one of its elements is called a positive loop (Richardson, 1986). A positive loop is often defined by the fact that an initial change in any variable eventually brings self-change in the original direction. A causal loop that characteristically tends to diminish or counteract a change in any one of its elements is called a negative loop (Richardson, 1986). The mental model conceived through the interactions of positive loops and negative loops are highlighted in following heading model structure and behavior.

4) MODEL STRUCTURE AND BEHAVIOUR

4.1) Model boundary

Model boundary creates a space where interactions of the interlinked departments describe a closed system. In our case quality assurance department, supply chain department, human resource department, customer service department, accounts department and sales department of a Packaging company forms the model boundary and variables associated from these departments interact to create the dynamic patterns of growth and stability (Forrester, 1964).

4.2) Case study and feedback loops

A Packaging Company was established in the decade of 50's just to focus the printing and packaging of paper products; over the decades the company diversified their businesses in various forms of packaging from carton line to corrugation line and flexible line.

Company has started quality journey from inspection to quality control department containing number of quality inspectors which keep on checking the quality of incoming supplies and finished products as per the mutual agreed limits between the customers and company. In 1994 when first product standard Quality Management System ISO 9001 came into existence, company has decided to have the ISO 9001 Quality Management System for Flexible packaging line. A new department named Quality Assurance (QA) department was formed with two dedicated employees to go for ISO certification. In this Quality Management standard there are many quality practices but quality auditing is key practice which contributes the main role in the organizational excellence. The first task of the QA department was to prepare and develop the team of internal quality auditors, ten persons have been chosen from different departments and a renowned certification body SGS Malaysia was asked to conduct Five Days Training Workshop for the development of first party auditors. The employees, who are selected for the first party auditor training, are trained for various steps of auditing right from gap analysis to audit preparation and audit conduction (Gerard W Paradis 1996). Trained internal quality auditors were prepared to conduct not only first party audits for ISO certification but also identify the areas of improvement for enhancing the supply chain performance considering, order fill rate, perfect order fulfillment, reduced number of customer complaints and reduction in warranty claims and product rejections. After every 6 months, a training workshop has been conducted to develop more quality auditors; the trained and qualified auditors are capable to identify more opportunities for improvement. Auditor leaving time is linked with the employee turnover or the employee leaving rate which is usually around 5 years as an average as per the documents of the human resource department. Figure 1 describes why Audit Planning and Assessment Loop are important; this loop explains who the audits are being planned assessed. For first party audit, quality manager issues the audit notification two weeks before the audit conduction and internally groomed and trained auditors conduct the audit planning and trail of questions to be asked during the audit session.

Each auditor conducts the audits in every week as per the annual audit schedule prepared by the Quality Assurance department. After the audit, audit report is submitted to Quality Assurance department.

Quality Assurance Manager is supposed to issue the corrective action requests (CARs) and preventive action requests (PARs) based on observations and non-conformances highlighted during the first party audit. CARs and PARs are issued and sent to concerned department for detailed investigation. Figure 4 portrays the issuances process of non-conformances.

The input to issue the CARs and PARs are as under:

1) Non-conformities highlighted by the first party auditors, second party auditors and third-party auditors;
2) Observation shared by the top management or any stakeholder of the company;
3) Any best-proven practice that is suggested by the third-party auditor or management representative;
4) Feedback from the customers in the form of complaints;
5) Government legal and regularity requirements;
6) Opportunities for improvement as a result of benchmarking or applicable suggestions.

CARs and PARs have been issued to concerned department heads or the process owners to improve the operations within the work area. Detailed discussions, group work and meetings have been conducted to identify the root causes using seven basic quality tools for effective implementation shown in Figure 4.

Quality Assurance Manager sends one copy of nonconformity report to Quality Control department as well as the concerned department for parallel investigation. The ultimate objective is to improve the system. This investigation will be discussed in the customer complaints meetings if the documentation found effective, CARs and PARs will be closed otherwise quality assurance manager issued CARs and PARs against the customer complaint or any non-conformity or observation for improvement purpose. CARs and PARs will also be issued as well by third party auditor either at the time of certification audit or surveillance audit or renewal audits. CARs/PARs issued by the first party auditor are supposed to close within three months after the verification of the appropriateness of documentation whereas CARs/PARs issued by third party auditor is closed by the third-party auditor at the time of surveillance audit which is usually done after six month or one year.

The purpose of the detailed investigation is to eliminate the root cause and to improve the system not only addressing the non-conformity issues but also to explore the suggestions and opportunities for improvement (OFIs) for the supply chain performance as shown in Figure 2: Variety of indices of supply chain performance was taken into consideration for this model and translated in the supply chain performance score shown in the Appendix C Table1 and Table 2.

The company records show that there are five customer complaints. Figure 2: this is basically the extension of loop Audit Planning and Assessment Loop mentioned in Figure 1. Supply Chain Performance moves around the Opportunities for Improvement (OFI) and the detailed effective documentation in terms of departmental operating procedures, quality plans, work instruction and system operating procedures. Effective documentation and root cause analysis reduce product rejections and warranty claims, enhanced order fill rate and perfect order fulfillment and reduced number of customer complaints. These are the established indicators of the improved supply chain performance.

The demand of sector specialists and competent auditors is mentioned in the Figure 3. Six departments in a Packaging company make the situation complicated. The departmental operations are complex in nature and only the competent auditors can unveil the improvement areas for supply chain performance. Competent auditor along with the sector specialist not only prepares the audit plan properly but also identifies the areas for improvement in the system due to his auditing skills and trail of questions. The standard relies too much on people's interpretations of quality, particularly those of auditors (Rouzbeh, 1999).

For third party audit and accreditation audit, competent auditor is supposed to plan the audit, his auditing skills jot down the audit details and quality manager extends his support to execute the audit plan with the support of departmental heads. Consequently, the well plan audit enhances the audit performance. The comprehensive audit plan measures the audit performance. Well documented and well-prepared audit questionnaire establish the trails of questions to explore the opportunities for improvement. Corrective and preventative requests have been issued to concerned departments for detailed investigation on the basis of opportunities for improvement (OFI). Addressing the root cause will improve the supply chain performance. Hierarchy of the documentation and system operating procedures are set up to ensure the systems are maintained, monitored, modified and improved. (Hunt & Gilmour 1996).

Improvement areas shared by the third-party auditor and sector specialists helps to set the budget for the application of system improvement tools and quality programs that consequently enhance the supply chain performance. In supply chain performance some indicators have been established like order fill rate, perfect order fulfillment, supply chain cost, warranty claims and product rejections (Beamon, 1998). All these indicators can be translated into the supply chain performance score mentioned in Appendix C Table 1, and Table 2. Opportunity to improve may relate with product audit, process audit, personnel audit and the system audit. The name of the company and data is normalized to protect the proprietary nature of the company. The third-party audit date may be rescheduled but quality of the competent auditor is the first priority always.

Figure 5: explains the loop of documented actions which are not effective. In effective documentation indicate the company staff is not taking the investigations seriously so training for team building and attitude development is required. When the documented actions found effective; CARs/PARs are closed immediately and outcome of the actions communicated to the customers and concerned sales executive mentioned in Figure 6:

Figure 7: explains the loop of budgetary constraint for improved quality programs. Breakthrough improvement and stair case function improvement (Kaizen Improvement) both bring the change within the organization. What type of quality program is required, what software can contribute what techniques is recommendable all come from the valuable input of the auditors. Starting various initiatives like 5S, Six Sigma, Quality Function Deployment (QFD) and enhancing investment for low cost supply chain initiatives like minimum order quantity and safety stocks of inventory can contribute for supply chain performance. Representatives of the top management must show the involvement in such newly initiated quality programs within the organization to gain momentum and to encourage willingness of all members of stakeholders (Paul Piplani, 2000).

Continuous improvement is not the knee-jerk, it is an effort to investigate causes and overcome such hurdles that produce non-conformities in the organization (Shackleton, 1998).

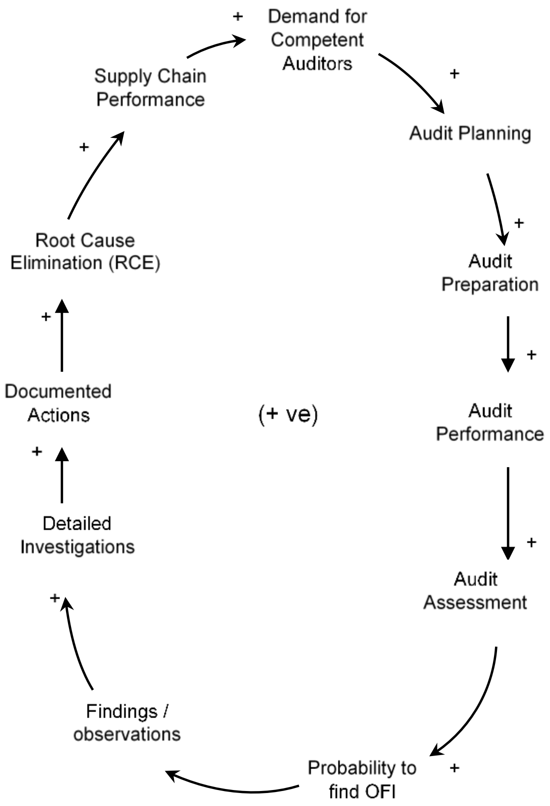

Figure 1: Audit Planning & Assessment Loop

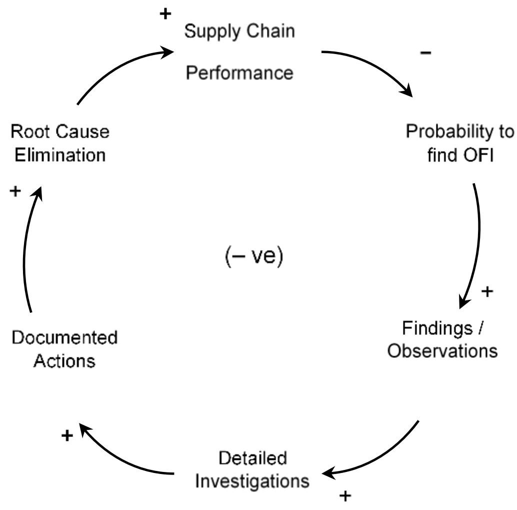

Figure 2: Supply Chain Performance

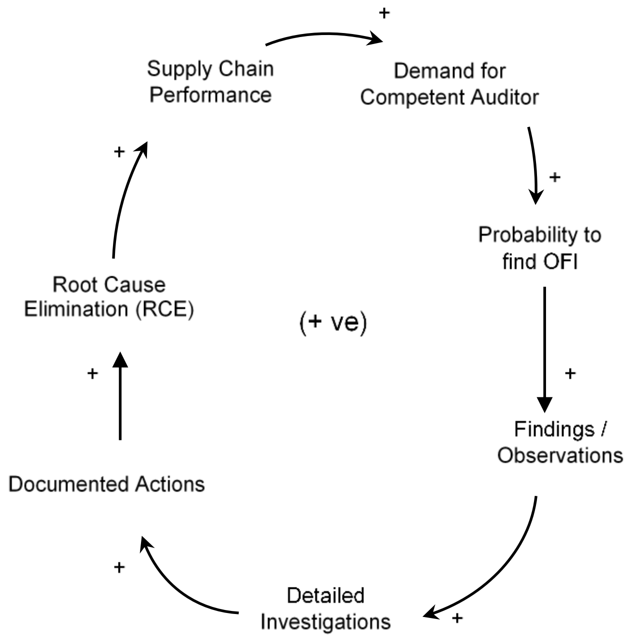

Figure 3: Loop of Competent Auditor

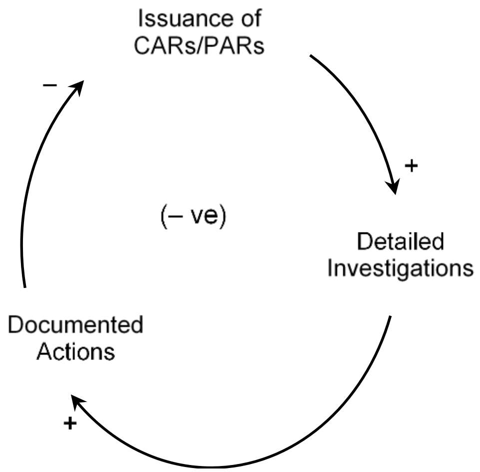

Figure 4: Loop of CARs/PARs

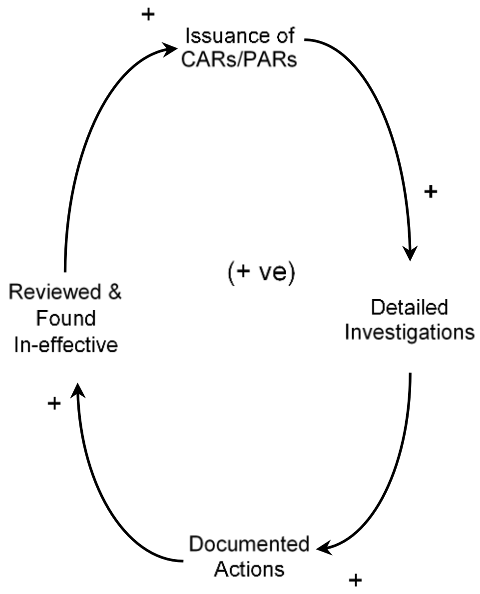

Figure 5: Loop of In-Effective Documents

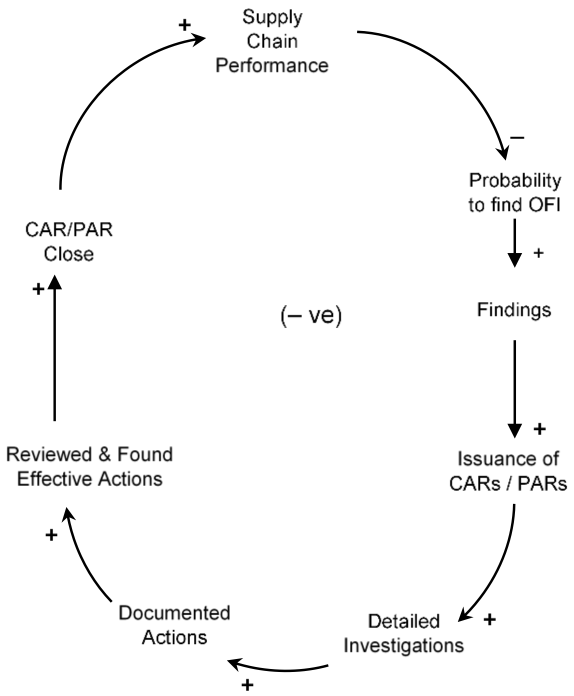

Figure 6: CARs/PARs Closed Loop

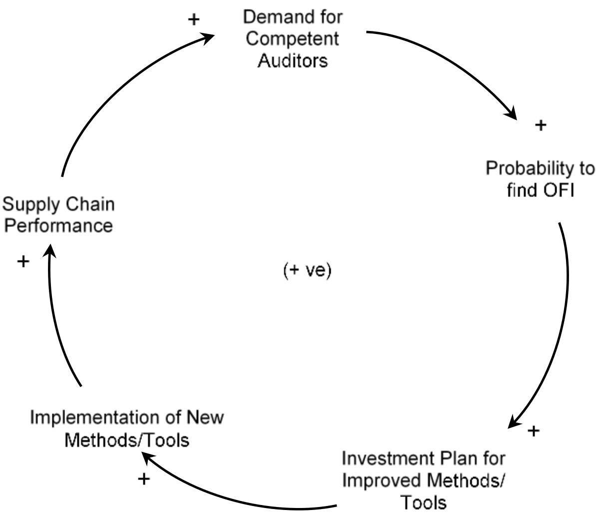

Figure 7: Loop of Investment for Improved Quality Programs

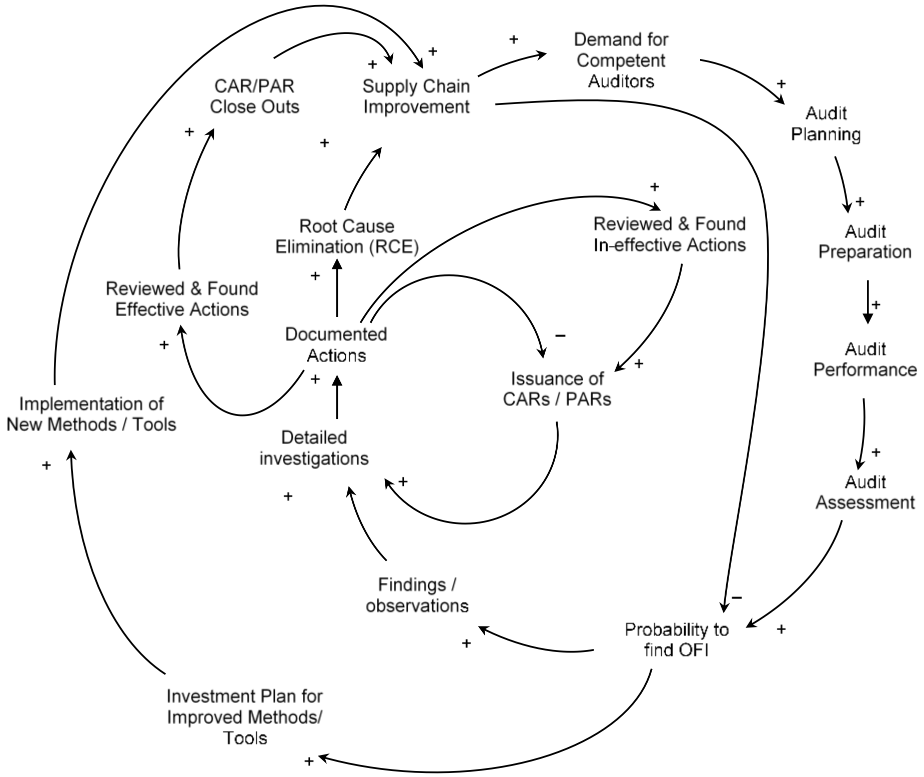

Figure 8: Dynamic Hypothesis of Quality Auditing for Supply Chain Performance

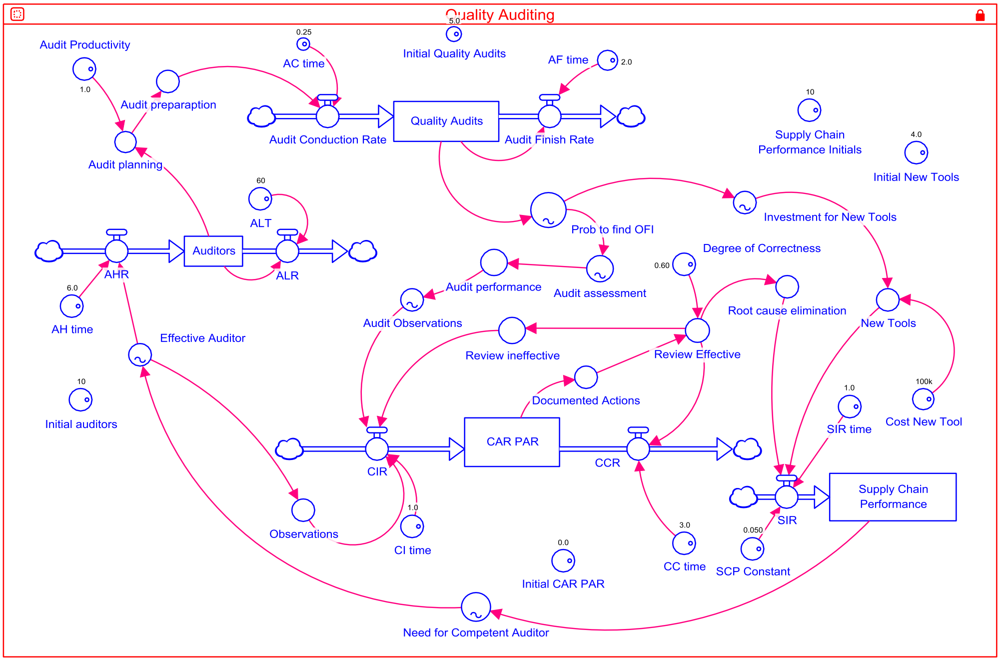

Figure 9: Level and Rate Diagram of the Model

4.3) Model behaviour base run graphs

Level and rate diagram of the model has been taken as STELLA Screen shown in Figure 9. Behavioural pattern over the passage of time depict the real-life happenings of the organization. These base run graphs mentioned in Figure 10. indicate as the audit increases the supply chain performance increases. It is interesting to know after achieving the quality certification the stock of number of audits declined because of the less management pressure and the pressure of the third-party bodies. As the news communicated for the surveillance audit, stock of audits starts increasing including first party audit and preparing the company for the surveillance audit conducted by the third-party certification body SGS. Consequently, the cumulative effect of different supply chain indices gives the increased growth in supply chain performance score as compared to the linear trend in the initial audits. Internal Quality Audits shall be scheduled by quality assurance manager on the basis of annual quality auditing plans and against the non-conformities highlighted by the different auditor during the audits. Auditors should be from those departments which are not being audited. (**Novack, 1995**) whereas third-party audits are conducted by the IRCA registrar and approved auditors. The scatter diagram (Figure 11) between quality audits and supply chain performance indicates for short duration of time when the number of audits declines the supply chain performance score also declines.

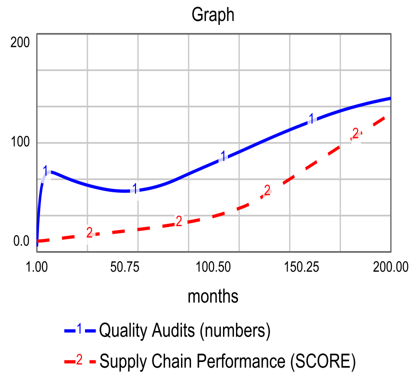

Figure 10: Quality Audits and Supply Chain Performance

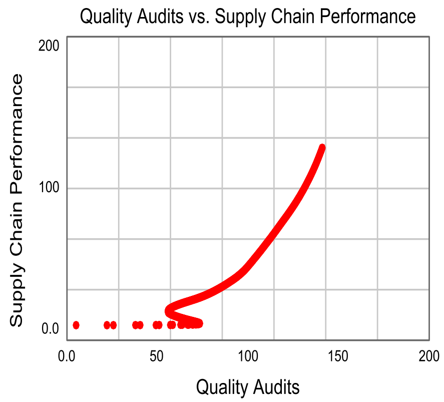

Figure 11: Scatter Diagram between Quality Audits and Supply Chain Performance

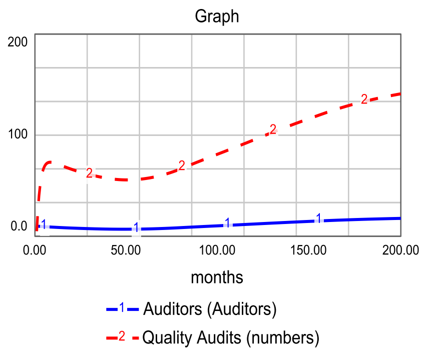

Figure 12: Auditors and Quality Audits

Figure 13: Scatter Diagram between Auditors and Quality Audits

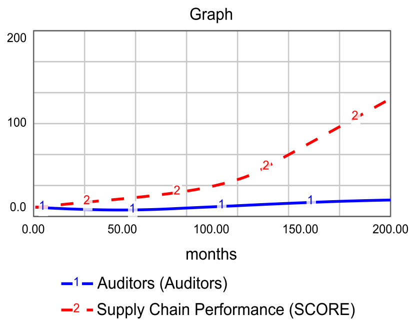

Figure 14: Auditors and Supply Chain Performance (Base Run)

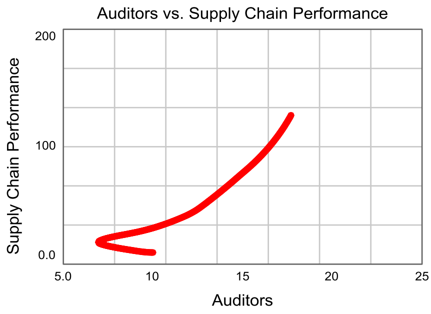

Figure 15: Scatter Diagram between Auditors and Supply Chain Performance (Base Run)

Above-mentioned graphs shown in Figure 12 indicates that a trained auditor is ambitious to conduct the audits and more auditors means more audits in all areas of the company. Trained auditors may leave the organization or may retire decreasing number of quality audits as it is quite visible from the Figure 13 Trained auditors whether they are the company employees for the first party auditors or the competent auditors from the renowned certification body develop the comprehensive audit plan covering four aspects like product audit, personnel audit, process audit and system audit. Their comprehensive approach improves the supply chain performance score as it is obvious from the Figure 14 Auditors and Supply Chain Performance and Figure 15. Scatter Diagram between Auditors and Supply Chain Performance.

Figure 16 to Figure 19 generate interesting patterns. More auditors mean more opportunities for improvement (OFIs) as a result there are more corrective action requests (CARs) and more preventive action requests (PARs).

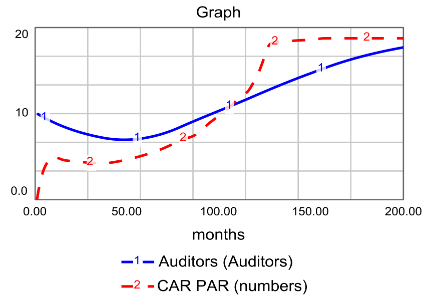

Figure 16: Auditors and CARs/PARs (Base Run)

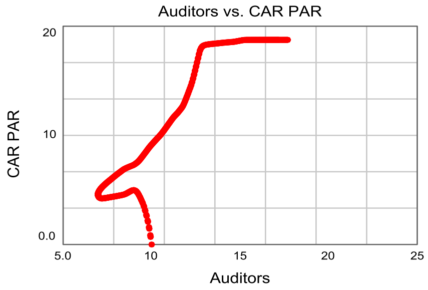

Figure 17: Scatter Diagram between Auditors and CARs/PARs (Base Run)

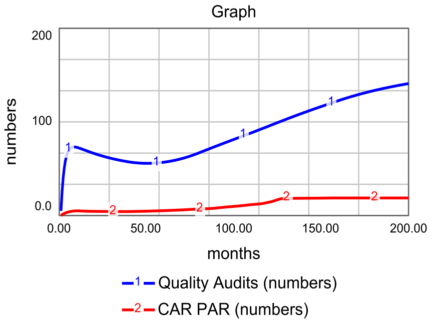

Figure 18: Quality Audits and CARs/PARs (Base Run)

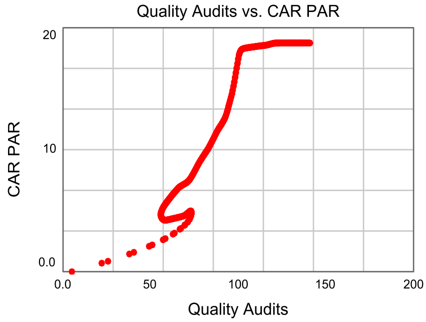

Figure 19: Scatter Diagram between Quality Audits and CARs/PARs (Base Run)

5) POLICY EXPERIMENTS

Models created for policy design perspective must incorporate multiple patterns potentially existing in the system and observed and recorded at different times and locations, so that the mechanisms of change from one pattern to another can be searched through experimentation (Saeed, 1991). Experimentation with the model not only allows us to understand the diversity of patterns but it also helps us to unveil the loops and critical elements which have pronounced effect on multiple stocks of critical variables. Various policies were designed and tested either on the basis of parametric changes or on the basis of structural changes in the mode. Primarily, policies tested are based on sensitive parameters and a search of policy maker was continued to determine the policy levers (Duggan, 2008) for improved supply chain performance. Secondly, policy experiments are performed on the structural changes having a base of mental intuition and perception about the problem solution. This is the equation perspective to optimization.

5.1) Model response to parametric changes

5.1.1) Policy run 1 (enhancing auditor productivity)

Auditor productivity represents the auditing skills of the auditor. Competent auditors are productive in nature they avoid easy audits they prepare the audit properly as the result productivity of the audit is enhanced. Enhanced productivity boosts the supply chain performance. Auditor productivity is not technological oriented because of the absence of machine or equipment (Romer, 1990). Well trained, educated and experienced auditors can easily identify the opportunities for improvement (OFIs). Enhancing the auditor productivity from 1 audit per auditor per month to 2 audits per auditor per month is an uphill task that requires rigorous training and motivation for the conduction of successful audits. An auditor is often viewed as guide to give suggestions for improvement and there is a responsibility of the quality assurance manager to make these suggestions to be the part of operational departmental procedures. (BSI International Training 1995) With enhanced auditor productivity gives the results as per our expectations, number of quality audits decreases (mentioned in Figure 20), supply chain performance increases (mentioned in Figure 21) CARs/PARs and opportunities for improvement (OFIs) gets the level of saturation (mentioned in Figure 22 and Figure 23). Figure 24 shows the contrary results to our pre-simulation expectation, stock of auditor's increases with enhanced auditor productivity is a surprising result. Auditor productivity has gone up as mentioned in Figure 25.

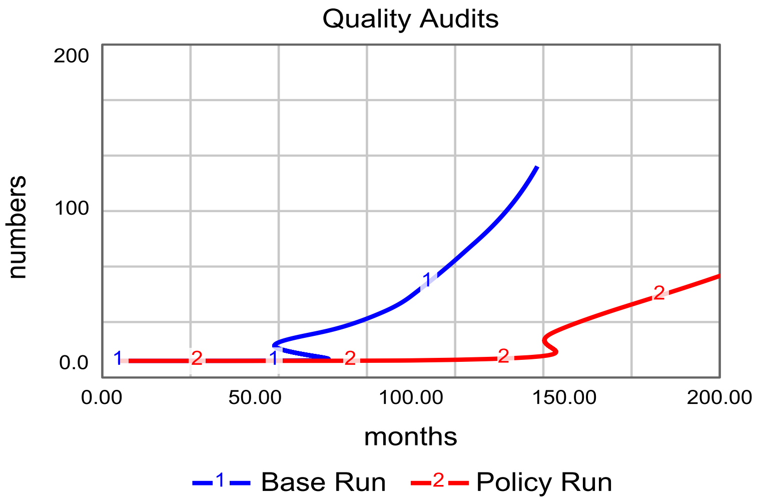

Figure 20: Comparison of Quality Audits between Base Run and Policy Run

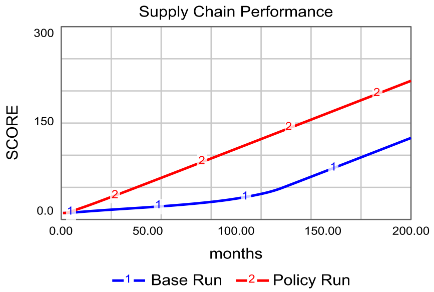

Figure 21: Comparison of Supply Chain Performance between Base Run and Policy Run

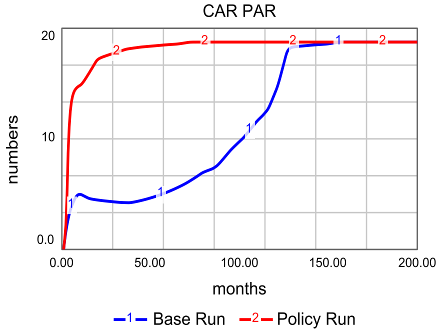

Figure 22: CARs/PARs between Base Run and Policy Run

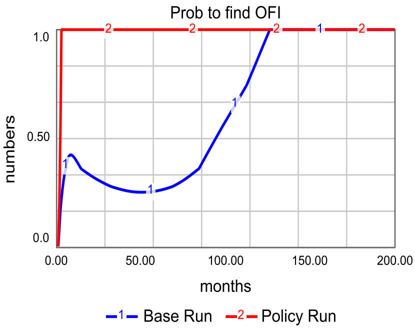

Figure 23: Comparison of Prob to find OFIs Between Base Run and Policy

Figure 24: Comparison of Auditors between Base Run and Policy Run

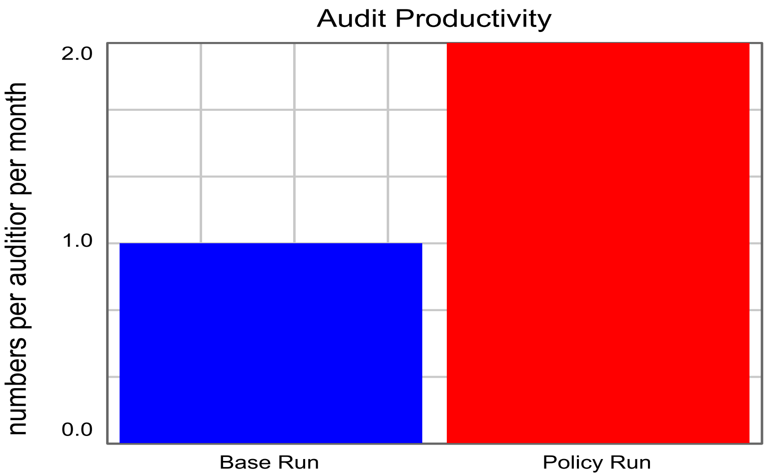

Figure 25: Comparison of Audit Productivity between Base Run and Policy Run

5.1.2) Policy run 2 (increasing investment from 1 to 2 million and deploying low cost improvement initiatives)

Increased investment in the deployment of new quality tools like Six Sigma, Design for Experiments (DOEx), Quality Function Deployment, Total Productive Maintenance (TPM), 5S and certifications like ISO 9001, ISO 14001, ISO 18001, HACCP, and deploying the low cost improvement supply chain initiatives like determining the Economic Order Quantities, applying the RFID, Bar Code Scanning, EDI, safety stocks and service levels, establishing the supplier development programs can enhance the supply chain performance.

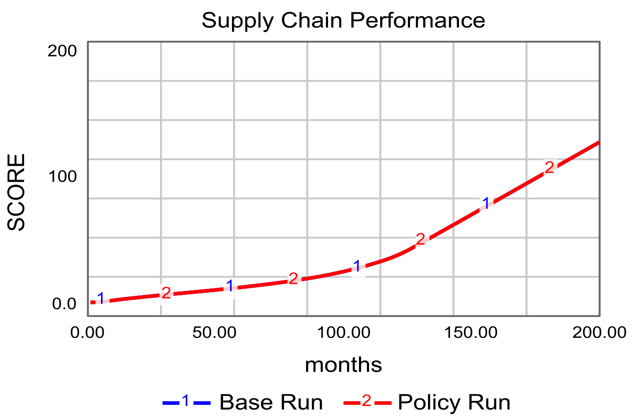

Figure 26: Supply Chain Performance curves overlap for Base Run and Policy Run

When the Initial Tools/Programs are double from 4 to 8 Supply Chain Performance remains same. Both Curves overlap each other as mentioned in Figure 26.

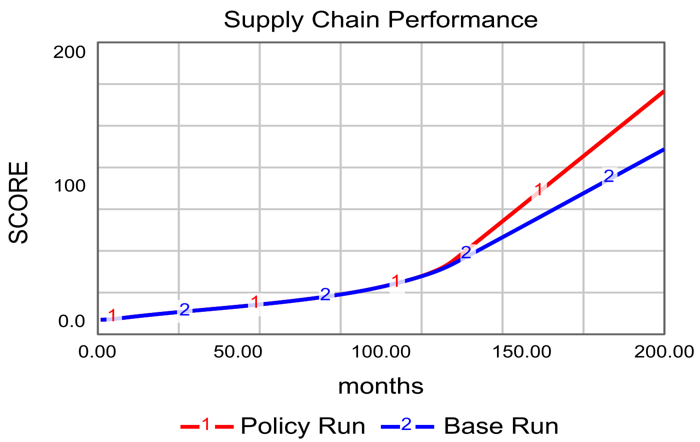

Figure 27: Comparison of Supply Chain Performance curves for Base Run and Policy Run

When the Investment in new Tools/improvement programs is double from 1 million to 2 million Supply Chain Performance increases after 8 years as indicated in Figure 27.

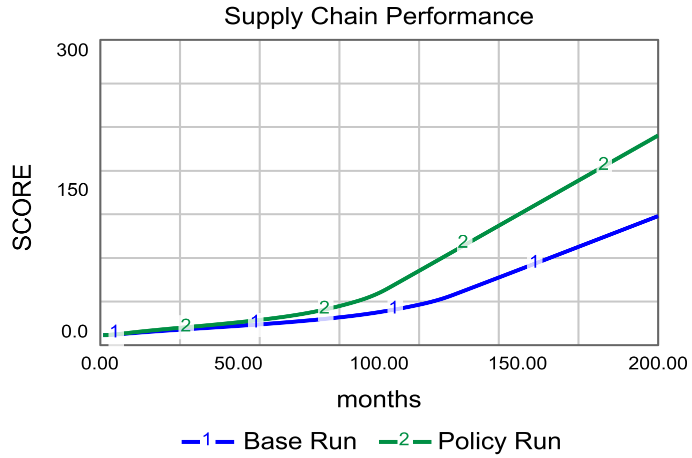

Figure 28: Comparison of Supply Chain Performance curves for Base Run and Policy Run

When the Low-cost improvement initiatives is doubled while reducing the cost from Rs 100,000 to Rs 50,000; there is an opportunity to deploy more quality tools with the same amount of quality budgets and after the effective implementation of more tools; consequently, supply chain performance increases after 4 years as indicated in Figure 28.

5.2) Model response to structural changes

5.2.1) Policy run 3 enhancing the degree of correctness (from 60 percent to 90 percent) /effective documentation

Effective documentation can improve the supply chain performance. Effective documentation (as mentioned in Figure 29) is the result of degree of correctness of the root cause identified and addressed so that such problem can not appear in future. Properly identified root causes improve the system as a result of non-conformance report has reduced number of corrective action requests (CARs) and preventive action requests (PARs) as mentioned in Figure 30. Strictness to adherence to National / International product regulations and CARs/ PARs can only be closed if the auditor is evaluated the effectiveness of the documentation and quite satisfied with its implementation.

But it is interesting to unveil this reality that it has no effect on supply chain performance as mentioned in Figure 31. Base run and policy run supply chain performance curves overlap each other. Same is the behaviour pattern of the curves of Auditors mentioned in Figure 32 and curves of Quality Audits mentioned in Figure 33.

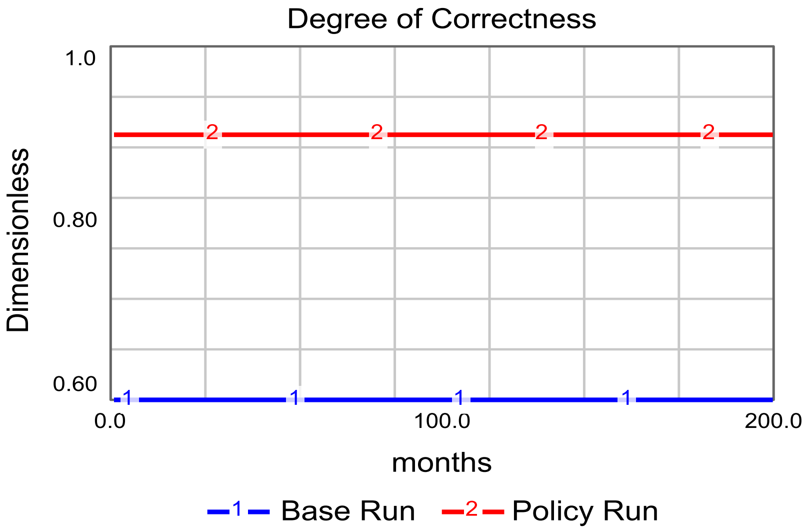

Figure 29: Comparison of Degree of Correctness between Base Run and Policy Run

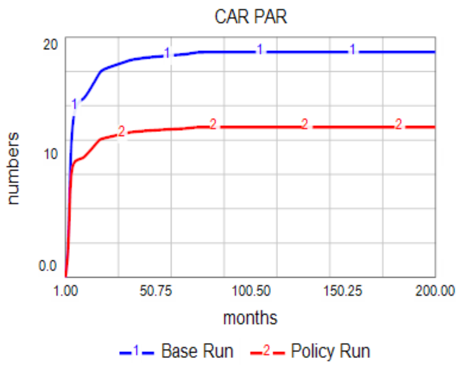

Figure 30: Comparison of CARs/PARs Between Base and Policy Run

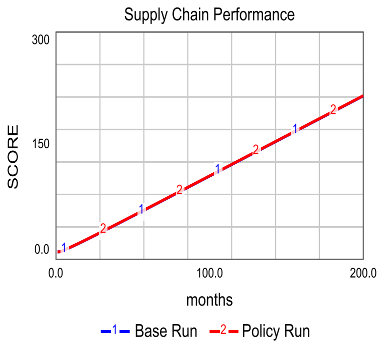

Figure 31: Comparison of Supply chain Performance between Base & Policy Run

Figure 32: Comparison of Auditors between Base Run and Policy Run

Figure 33: Comparison of Quality Audits between Base Run and Policy Run

6) CONCLUSIONS

While experimentation with the model and exploration of the policies, care has been taken the behavior generated by the model should represent the real-life behavior of a Packaging Company. After testing the model for structure verification, parametric verification, extreme condition variation and dimensional consistency verification (Sterman, 2000); policies based on parametric changes and structural changes have been deployed. Policy interventions have given the guidelines how we can enhance the supply chain performance score with the application of different policies as discussed above. Concept of feedback system structure for organizing the explicit and tacit knowledge about the system (Saeed, 2008), explores the avenues that make the system better behaved over a period of time. Translation of dynamic hypothesis into a simulated model of stock and flow diagram provides insight to management about the causes of behavior. This paper proposes the policies for the management of a Packaging company for enhanced supply chain performance. The policies are thought provoking and eye-opening because pre-simulation predictions of the researcher were contrary to the actual policies suggested by the model. Policies suggested on the basis of an integrated simulated system dynamics model are the valuable contribution to literature and boost the usability of the model in different scenarios for many organizations. It is interesting to know that effective documentation of the root cause helps to reduce the number of corrective and preventive actions requests but there is no change in the supply chain performance. Introducing the increased number of quality programs without proper budget and implementation strategy has no impact on the supply chain performance. Cost of the quality program does not matter what matters the effective implementation of the quality program and quality budget for the deployment of the quality program.

7) LIMITATIONS

The authors have taken the pain to capture all the undying structures of quality auditing for supply chain performance. Types of auditing like first party audit, customer audits, third party audit and accreditation audit are aggregated in the word quality auditing and separately not discussed. It is very important input for the future researcher to consider the types of auditing separately and see the influence of every auditing type separately on the supply chain performance. The second important limitation is the aggregation of quality programs/tool; it is really important to explore the influence of each quality program on supply chain performance while enriching the model with more stocks and associated flows.

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APPENDIX A

Model Equations

Top-Level Model:
Auditors(t) = Auditors(t - dt) + (AHR - ALR) * dt
INIT Auditors = Initial_auditors
INFLOWS:
AHR = (Effective_Auditor)/AH_time
OUTFLOWS:
ALR = Auditors/ALT
CAR_PAR(t) = CAR_PAR(t - dt) + (CIR - CCR) * dt
INIT CAR_PAR = Initial_CAR_PAR
INFLOWS:
CIR = (Observations+Audit_Observations+Review_ineffective)/CI_time
OUTFLOWS:
CCR = (Review_Effective)/CC_time
Quality_Audits(t) = Quality_Audits(t - dt) + (Audit_Conduction_Rate - Audit_Finish_Rate) * dt
INIT Quality_Audits = Initial_Quality_Audits
INFLOWS:
Audit_Conduction_Rate = Audit_preparaption/AC_time
OUTFLOWS:
Audit_Finish_Rate = Quality_Audits/ AF_time
Supply_Chain_Performance(t) = Supply_Chain_Performance(t - dt) + (SIR) * dt
INIT Supply_Chain_Performance = Supply_Chain_Performance_Initials
INFLOWS:
SIR = (Root_cause_elimination+New_Tools)*SCP_Constant/SIR_time
AC_time = 0.25
AF_time = 2
AH_time = 6
ALT = 60
Audit_assessment = GRAPH(Prob_to_find_OFI)
(0.000, 0.0), (0.100, 4.8), (0.200, 9.6), (0.300, 16.2), (0.400, 22.1), (0.500, 32.1), (0.600, 39.9), (0.700, 50.6), (0.800, 57.9), (0.900, 74.2), (1.000, 100.0)
Audit_Observations = GRAPH(Audit_performance)
(0.0, 0.0), (10.0, 1.0), (20.0, 2.0), (30.0, 3.0), (40.0, 4.0), (50.0, 5.0), (60.0, 6.0), (70.0, 7.0), (80.0, 8.0), (90.0, 9.0), (100.0, 10.0)
Audit_performance = Audit_assessment

Audit_planning = Auditors*Audit_Productivity
Audit_preparaption = Audit_planning
Audit_Productivity = 1
CC_time = 3
CI_time = 1
Cost_New_Tool = 100000
Degree_of_Correctness = 0.6
Documented_Actions = CAR_PAR
Effective_Auditor = GRAPH(Need_for_Competent_Auditor)
(0.000, 0.000), (0.200, 0.198), (0.400, 0.485), (0.600, 1.406), (0.800, 1.584),
(1.000, 1.752), (1.200, 1.822), (1.400, 1.861), (1.600, 1.901), (1.800, 1.931),
(2.000, 2.000)
Initial_auditors = 10
Initial_CAR_PAR = 0
Initial_New_Tools = 4
Initial_Quality_Audits = 5
Investment_for_New_Tools = GRAPH(Prob_to_find_OFI)
(0.000, 0), (0.100, 0), (0.200, 70000), (0.300, 110000), (0.400, 160000), (0.500,
210000), (0.600, 300000), (0.700, 370000), (0.800, 470000), (0.900, 700000),
(1.000, 990000)
Need_for_Competent_Auditor = GRAPH(Supply_Chain_Performance)
(0.0, 0.00), (50.0, 1.19), (100.0, 2.57), (150.0, 4.16), (200.0, 5.25), (250.0, 6.44),
(300.0, 8.02), (350.0, 10.00), (400.0, 12.38), (450.0, 16.93), (500.0, 20.00)
New_Tools = Investment_for_New_Tools/Cost_New_Tool
Observations = Effective_Auditor*2
Prob_to_find_OFI = GRAPH(Quality_Audits)
(0.0, 0.000), (10.0, 0.011), (20.0, 0.057), (30.0, 0.111), (40.0, 0.170), (50.0,
0.218), (60.0, 0.280), (70.0, 0.362), (80.0, 0.557), (90.0, 0.745), (100.0, 1.000)
Review_Effective = Documented_Actions*Degree_of_Correctness
Review_ineffective = 1-Review_Effective
Root_cause_elimination = Review_Effective
SCP_Constant = 0.05
SIR_time = 1
Supply_Chain_Performance_Initials = 10
{ The model has 42 (42) variables (array expansion in parens).
In 1 Modules with 1 Sectors.
Stocks: 4 (4) Flows: 7 (7) Converters: 31 (31)
Constants: 16 (16) Equations: 22 (22) Graphicals: 6 (6)}

APPENDIX B

Variables with Base Run and Policy Run Parametric Values

Variables	Description	UOM	Base Run Parametric Value	Policy Run Parametric Value
Initial auditors	Initial Number of Auditors	Auditors	10	10
AH Time	Auditors Hiring Time	Months	6	6
AL Time	Auditors Leaving Time/Auditors Turnover	Months	60	60
Audit Productivity	Auditor Productivity	Number of audits per auditor per month	**1**	**2**
AC Time	Audit Conduction Time	Months	0.25	0.25
AF Time	Audit Completion Time	Months	2	2
CI Time	CARs/PARs Issuance Time	Months	1	1
Initial CAR PAR	Initial number of Corrective Action Requests/Preventative Action Requests	Numbers	0	0
CC Time	CARs/PARs Closed Time	Months	3	3
Initial New Tools	Initial New Tools in practice	Numbers	**4**	**8**
Degree of Correctness	Degree of Documentation Correctness	Dimensionl ess	**0.6**	**0.9**
SCP Time	Supply Chain Performance Time	Months	1	1
Cost New Tool	Cost of New Tool or Quality Program	Rupees per new tool	**100,000**	**50,000**
Supply Chain Performance Initial	Supply Chain Performance Initial	SCORE	10	10
Initial Quality Audits	Initial Quality Audits conducted by Quality Manager and his team	Numbers	5	5
SCP Constant	Supply Chain Performance Constant	Fraction SCORE per Number	0.05	0.05

APPENDIX C

Table 1: Basis of Supply Chain Performance Score

Indicators	UOM	Equivalence	SCP SCORE
Order Fill rate	%	% age*1/20 = Points	
Number of complaints	Nos	0=10 Points 20=0 Points	
On time deliveries			
Perfect Order Fulfillment	%	% age*1/10 = Points	
Supply chain cost in terms of warranty claims and rejections	Rs	Rs 0 = 150 *1/20 Points Pak Rupees 1,000,000 = 0 Points	

Pakistan Open Market Forex Rates
As on Sat, Apr 08 2017, 15:15 PST (GMT+5) US Dollar 1 = Pak Rupees 106.65

SCP Score = Order fill rate + Number of Complaints/Observations + Perfect Order
Fulfillment + SCC/Warranty Claims
Points = SCORE

Table 2: Supply Chain Performance Score

Supply Chain Indicators	UOM	Normalize Figure	Individual SCORE	Supply Chain Performance SCORE
Order Fill rate	%	60	3	
Number of complaints/ Observations	Nos	20	0	
Perfect Order Fulfillment	%	55	5.5	
Supply chain cost in terms of warranty claims and rejections	Pak Rupees	800,000	1.5	
SCP SCORE				**=3+1.5+4.5+0 =10**