Causal Loop Analysis and Improvement Areas of AS 9100 Aerospace Quality Management System Implementation in Turkish Aerospace and Defence Industry Supply Chain

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***Abstract*— Implementing Aerospace Quality Management system in an organization in theory will achieve on-time delivery, product conformity and acceptable price, which will result in Customer Satisfaction. However, system dynamics has to be considered for all systems, which determines and analyses feedback effects of components in the system. This study investigates these dynamic effects arising from various aspects that organizations are facing during implementation of the aerospace quality management system in Turkish defence and aerospace industry. Results achieved, and information collected through site activity is used to develop causal loop diagram. Requirements of the AS 9100 standard are interpreted to propose improvement opportunities. Causal Loop diagram is validated by using a scientific method.**

Keywords*—AS 9100, aerospace and defence, quality management, system dynamics, causal loop, customer satisfaction,*

1 Introduction

Turkey's aerospace and defence industry is showing growth in recent years. Aerospace industry growth is line with increasing local and global demand in aviation and air transport. Defence industry growth is mainly result of Turkey's increasing defence needs due to geopolitical situation and conflicts in the region. Both sectors are using AS 9100 series of standards as a quality management system reference for improvement of supply chain performance. These standards are prepared by the involvement experts worldwide. Experts operate under the organization IAQG (International Aerospace Quality Group) while IAQG members are major manufacturers and players of aerospace and defence industries.

Improvement of supply chain is the key expectation from the implementation of this aerospace quality management system and expectations are solid from suppliers. All level suppliers shall provide right product, on time and with acceptable price level [11]. These three components (quality, on time delivery and price) are main drivers for customer satisfaction. In theory effective implementation of quality management system will provide the necessary output.

There are significant changes in supply chain management practices in the aerospace industry. These changes include restructuring and closer integration of supplier networks to achieve efficiency gains, delegating greater design and production responsibility to major suppliers through strategic supplier partnerships along with having key suppliers evolve greater system and subsystem integration capabilities, emphasizing a lifecycle view supply chain design and management to reduce lifecycle cost of products and systems, and building supply chain capabilities supporting maintenance and aftermarket logistics services as a major new strategic thrust to provide improved customer satisfaction and retain long-term customer loyalty [17]

However, system dynamics approach is to be considered for all systems, which expects that system components have feedback effect and results are not always achieved as expected.

Here we touch on the nature of feedback loops. People seldom realize the pervasive existence of feedback loops in controlling everything that

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changes through time. Most people think in linear, nonfeedback terms. However, a far more realistic perception would be a problem leads to action that produces a result that creates future problems and actions. There is no beginning or end. We live in a complex of nested feedback loops. Every action, every change in nature, is set within a network of feedback loops. Feedback loops are the structures within which all changes occur [18].

This issue is also a concern of industry and AS/EN 91XX series of standards are revised in 2016 for improved performance of the system.

This study focuses on customer satisfaction of the industry and prepared after on-site visit and interview results with Turkish aerospace and defence companies and their suppliers. Once cause loop diagram of the system is achieved, study also comes to conclusions how standard requirements help and positively affects organizations to a overcome these feedback effects. The study also includes evaluation on the validation of cause loop diagram and provides suggestions and basis for further studies by quantification of available information.

Customer satisfaction is becoming more and more important in aerospace and defence supply chain. Today's aviation and aerospace organizations are highly relevant same as defence organizations and defence industry organizations. Highly relevant can be explained in supply-demand structure and costly consequences when commitments cannot be kept. This will result in customer dissatisfaction.

When we refer to sector statistics and global aviation realizations and forecasts picture is pretty clear. Global passenger traffic results for 2016, showing a 6.3% increase in revenue passenger kilometres (RPK) compared to 2015. Until the year 2030 it is expected that air transport will keep it's growing structure [5].

According to forecast study carried out by Airbus, until the year 2034 new 32.585 aircraft will delivered by the manufacturers. This will aprroximately double the current passenger fleet from 17.354 to 35.749 aircrafts [2]. Major manufacturers Boeing ve Airbus 2004 – 2008 has been awarded more contracts that aircrafts they delivered in those years. Orders decreased as a result of in 2008 and 2009 as a result of global crisis. After overcoming the crisis in 2011 orders are again increasing [5].

IATA refers main industry suppliers for aviation industry as Airframe manufacturers and Engine manufacturers. New aircraft are bought directly from producers, usually with a significant delay between order and delivery. Manufacturers operate globally and concentrate on different size-classes of aircraft. Large aircraft on longer routes as well as some larger single-aisle aircraft operating on shorter distances are manufactured by limited number manufacturers. For medium-sized aircraft there are a number of additional suppliers. [3]

Engine suppliers also operate globally. Customers can usually choose among a number of different engines for a given airframe. Engines account for a significant part of the total cost of an aircraft and a high proportion of the cost of use. Airbus handles this huge manufacturing capacity by more than 1500 suppliers in 30 countries. Boeing supply network is consisting of more than 28.000 suppliers. According to Turkish civil aviation authority reports, overall number of passenger aircrafts increased from 162 to 540 from 2003 to 2016. Seat capacity has changed from 27.599 to 100.365 and Cargo capacity has increased from 302.732 kg to 1.821.600 kg. [4]

Turkey is now working on various projects for improvement of defense and aerospace sector. There are many new programs and projects available such us development of main battle tank, fighter aircraft, commercial aircraft, attack helicopter, national corvette and frigate. Unmanned aircraft, satellite, national infantry rifle, basic trainer and ground attack turboprop aircraft and various missile development projects. These projects are under coordination of Undersecretary of Defense Industry is investing on supply chain to meet defense requirements of Turkey.

Based on high level policy Turkey is investing on development and improvement of local supply chain for years. There are targets of improving the use of local sources for aerospace and defence projects. % 65 local source utilization achieved for weapon systems and equipment in MILGEM corvette Project [10]. However SWOT analysis results Turkish aerospace sector conducted in 11th transportation forum still states supply from local sources as one of the weak aspects and boundary against fast development of the sector [13].

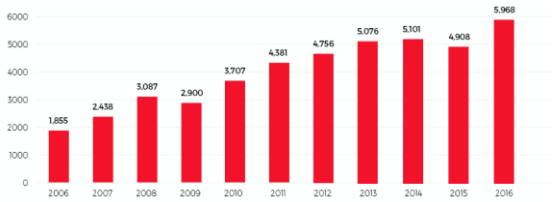

Figure 1. Total turnover of AS&D organizations of Turkey [7]

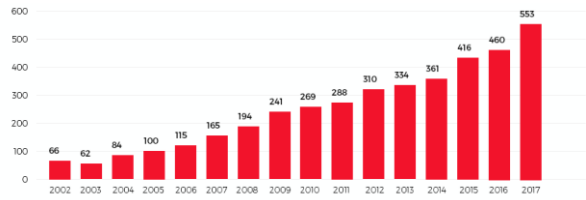

Figure 2. Number of defence projects of Turkey [7]

Sectors within this growth structure requires significant support from supply chain to achieve targets and maintain policies which leads to safety, reliability, profitability and sustainability.

2 Literature Survey

2.1 AS 9100 Quality Management System

Aerospace quality management system (AQMS) is a set of policies, procedures and implementation of these in an organization to achieve it's objectives while conforming with legal and other (customer, authority etc.) requirements.

System's start point is customer requirements and expected to result in customer satisfaction and products and services which overall will demonstrate results of the quality management system. These are achieved by implementation of policies and procedures in processes defined. All processes are planned, executed, monitored and measured.

Actions are taken to improve the system as a result of monitoring and measurement activities. Figure 1 illustrates the structure of management system based on continuous improvement model of Plan-Do-Check-Act defined first by Dr. J. Edward Deming, in 1960's and well known as Kaizen or continuous improvement model [12].

Kaizen is a Japanese philosophy that promotes small improvements made as a result of continuing effort. These small improvements involve the participation of everyone in the organization from the top management until the lower level employees. The long-term improvement is achieved by having the employees working gradually towards higher work standards [14].

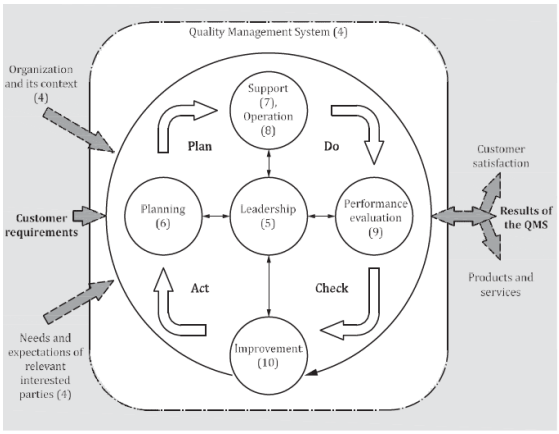

Figure 3. Representation of the structure of AS 9100:2016 Standard in the PDCA cycle

Controls on suppliers are by performance monitoring and assessments conducted by IAQG approved third party certification bodies to ensure that AS 9100 systems are effective and maintained effectively. Maintaining effective systems will prevent final customers to be affected by supply chain quality system failures.

2.2 System Dynamics

System dynamics is a method to enhance learning in complex systems. Just as an airline uses flight simulators to help pilots learn, system dynamics is, partly, a method for developing management flight simulators, often computer simulation models, to help us learn about dynamic complexity, understand the sources of policy resistance, and design more effective policies [9].

Aerospace quality management systems are designed in theory to achieve necessary outputs of improved quality, cost, and delivery performance. System also accepts dynamic nature system and applies corrective measures in case objectives cannot be achieved due to effects resulting in process failures which causes mainly policy resistance, procedures, human errors and human factors, resource inadequacy etc.

The effects we thought of in advance, or were beneficial, we call the main, or intended effects. The effects we didn't anticipate, the effects which fed

back to undercut our policy, the effects which harmed the system-these are the ones we claim to be side effects. Side effects are not a feature of reality but a sign that our understanding of the system is narrow and flawed [9].

Much of the art of system dynamics modeling is discovering and representing the feedback processes, which, along with stock and flow structures, time delays, and nonlinearities, determine the dynamics of a system. You might imagine that there is an immense range of different feedback processes and other structures to be mastered before one can understand the dynamics of complex systems. In fact, the most complex behaviors usually arise from the interactions (feedbacks) among the components of the system, not from the complexity of the components themselves [9]. System dynamics modeling is an iterative process and depicted in Figure 2. Figure 3 is informative about feedback effects in real world that are affecting the model.

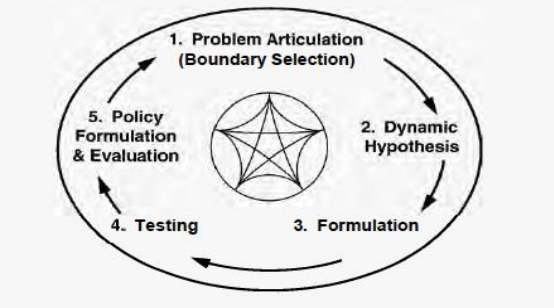

Figure 4. Iterative System dynamics modelling [9]

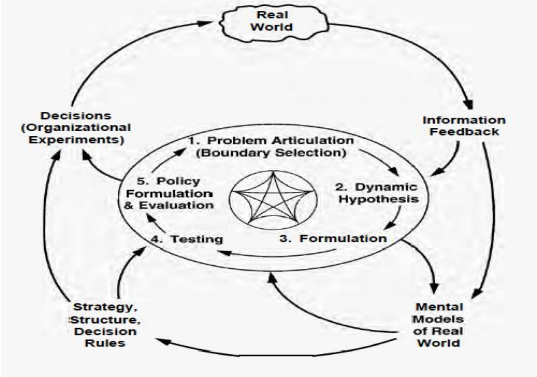

Figure 5. System dynamics modelling with real world feedback effects [9]

System dynamics is a method that can be applied to various problems in various subjects and sectors.

Dynamic nature of maintenance activities in manufacturing plants is analyzed for improving maintenance management process [19].

Problem identified that the "costs of the operation" were much higher than expected in sales process of computers was decided to be re-engineered with the aim of reducing the cost of selling to a level at which the organization would meet its targets. System dynamics is applied to reengineering of this value process [20].

Dynamic nature of online question and answer markets (including search engines) is modeled through causal loop diagram of system dynamics [21].

Quality systems have also interface with system dynamics. The experts have also searched this interface with link to total quality management.

Dynamic interactions been among subsystems of total quality management is identified. Implications of these interactions are captured by system dynamics model based on causal relationship [22].

Further study generated a Total Quality Management index (TQMI) based on causal relations that have been developed between sets of enablers and results of a Total Quality Management System [23].

Policy experimentations of Total Quality Management relations have been conducted to assess predefined scenarios by software support [24]

A system dynamics model is used to analyze the traditional energy consumption, alternative energy consumption and the CO2 emission performance until 2020 in China. A number of scenarios are simulated to examine the impact of different economic growth rates and policies on different combinations of energy uses and CO2 emissions in the future [25].

Dynamic systems principles are utilized in order to better contribute to the objective evaluation of an enterprise which implements a Business Excellence Model. The current practice of Static Business Excellence Models are compared to the Dynamic Systems that define the interaction of a system variables (as criteria, causes - results, etc.) giving the opportunity of more objective decision-making

evaluation with regard to the areas for continuous improvement [26].

Cost factor was analyzed in order to achieve the expected quality level of customer and a model was developed to show the effect of cost factors. Based on the effect of quality costs on the level of customer satisfaction, it has been proved that increasing prevention costs and decreasing external failure costs can directly improve the level of customer satisfaction via system dynamics [27].

System dynamics is used together with discrete event simulation in the logistics and supply chain context as decision support systems [29].

System dynamics based tool for assessing the performance of the Athens International Airport passenger terminal under different demand and resource deployment scenario is generated [30].

Causal Loop Diagram used as a useful tool to capture the structure of e-Business systems in order to achieve a better understanding of an e-Business model [31].

System dynamics is used for analyzing education, which is dynamic and complex system. In education systems many parameters are interrelated independently and student academic achievement is an important outcome. [32]

System dynamics is suitable for this research because it emphasizes multi-loop character of education system. It is powerful tool that can make future predictions for complex systems. Group model building was implemented among twenty managers to use the most important parameters in the model.

The examination of above papers generates the information that systems dynamics has a wide application area and applicable to many problems.

However literature review also indicated to an absence of a system dynamics view in the field of aerospace quality management systems. There were a only limited research about implementation of system dynamics modeling on management systems and none defined specific for AS 9100 system.

Main objective of the model will be enhancing Customer Satisfaction. Customer satisfaction is achieved by product conformity, on time delivery, and acceptable price level. This relation is based on international standard [11].

Table 1 defines the needs and expectations of interested parties from implementing quality management standards. The focus for the study is customer as an interested party and collects information from the market. The study determines what are the dynamics of customer satisfaction and what are the supporting factors in the standard to overcome discrepancies during implementation.

Table 1. Examples of interested parties and their needs and expectations

Interested party	Needs and expectations
Customers	Quality, price and delivery performance of products
Owners/shareholders	Sustained profitability Transparency
People in the organization	Good work environment Job security Recognition and reward
Suppliers and partners	Mutual benefits and continuity
Society	Environmental protection Ethical behaviour Compliance with statutory and regulatory requirements

On site studies and interviews confirmed that there is a reinforcing effect Order Quantity (ORD) to on time delivery (OTD), product conformity (QUA) and a balancing effect of price (PRI) on Order Quantity (ORD).

There are possible delays in these effects where we understand that this delay is the section where in the background quality management system is operating for improvement of organizations processes.

Direct increase in order quantity cannot result improvement of quality or on time delivery in an organization that do not have and effective AQMS.

AQMS will require a different mind-set including risk-based thinking, product safety concept, understanding the human factors. This will only be possible with leadership in the organization by understanding all interested parties needs.

Increase at the order quantity will only result in improvement of product conformity when quality management system is in place. This is the same for on time delivery. Organization has to implement principles and operational processes and procedures to improve;

Leadership,

Planning,

Support,

Operation,

Performance Evaluation

Improvement

modules of quality management system within the Context of the organization.

Main Industry has defined this need and AS 9100 series of standards are created by the direct involvement of sector representative under the umbrella of IAQG.

3 Methodology

3.1 Problem Articulation

The most important step in modeling is problem articulation. What is the issue the clients are most concerned with? What problem are they trying to address? What is the real problem, not just the symptom of difficulty? What is the purpose of the model? A clear purpose is the single most important ingredient for a successful modelling study. Of course, a model with a clear purpose can still be misleading, unwieldy, and difficult to understand. But a clear purpose allows your clients to ask questions that reveal whether a model is useful in addressing the problem they care about. Beware the analyst who proposes to model an entire business or social system rather than a problem. Every model is a representation of a system-a group of functionally interrelated elements forming a complex whole. But for a model to be useful, it must address a specific problem and must simplify rather than attempt to mirror an entire system in detail. [9]

Problem determined in this study in line with assumptions above is as follows; AS 9100 system implementation to achieve customer satisfaction is a specific target for organization. Discrepancies in processes may disable organization to achieve this target. Customers are demanding, correct product, on time with acceptable price whereas organization has a chance to know the basic variables that have reinforcing or balancing effects on these variables.

Modelling does not take place in splendid isolation. It is embedded in an organization and social context. Even before the modeling process per se begins, the modeler must gain access to the organization and identify the client [9] p 85. Model determined in this study also considers organization and social context. Furthermore One of AS 9100 standard requirements is also identification of context of the organization. Internal and external context definition is important for effective system design.

Determination of the time horizon is another aspect of modelling. Time horizon should extend far enough back in history to show how the problem emerged and describe its symptoms. It should extend far enough into the future to capture the delayed and indirect effects of potential policies. Most people dramatically underestimate the length of time delays and select time horizons that are far too short. A principal deficiency in our mental models is our tendency to think of cause and effect as local and immediate. But in dynamically complex systems, cause and effect are distant in time and space. [9] p 91

Considering nature of a sector and high level of expectations an organization involved should achieve customer satisfaction within one to two years of system implementation. IAQG requires the satisfactory customer satisfaction (on time delivery and product conformity) data shall be available for an organization to be certified. This requirement was 12 months recently. If we consider a system set up history of another 12 month. An organization shall define a minimum 2 years of a time horizon to achieve customer satisfaction from system start date. Considering the delays in system and as discussed during interviews a sustainable and stable aerospace and defence organization may require a five year time horizon to achieve satisfactory customer satisfaction.

3.2 Boundaries, Determination of Variables for Model

System dynamics includes a variety of tools to help you communicate the boundary of your model and represent its causal structure. These include model boundary diagrams, subsystem diagrams, causal loop diagrams, and stock and flow maps [9] pg 97. Our study is aiming to achieve causal loop diagram of the model.

Although generic structure of management system continuous improvement model provides a basis, variable determination is a task to be supported and completed by on site work.

Much of the data a modeler uses to develop a dynamic hypothesis comes from interviews and conversations with people in organizations. There are many techniques available to gather data from members of organizations including surveys, interviews, participant observation, archival data and so on. Surveys do not yield data rich enough to be useful in developing system dynamics models. Interviews are an effective method to gather data useful in formulating a model, either conceptual or formal.

If the purpose of your interviews is to develop a good model of the problem situation, you should supplement the links suggested by the interviews with other data sources such as your own experience and observations, archival data, and so on. In many cases, you will need to add additional causal links not mentioned in the interviews or other data sources. While some of these will represent basic physical relationships and be obvious to all, others require justification or explanation. You should draw on all the knowledge you have from your experience with the system to complete the diagram [9]

Semistructured interviews (where the modeller has a set of predefined questions to ask but is free to depart from the script to pursue avenues of particular interest) have proven to be particularly effective. [9]. p 157. Based on above consideration interviews have been conducted with 21 Turkish aerospace and defense companies and 10 experts are visited and interviews are conducted by quality and supply chain managers as well as experts themselves.

Based on interview activity and evaluation of output parameters in Table 1 from customers perspective are determined as most crucial variables to achieve customer satisfaction as an output from system implementation. The variable names in causal diagrams and models should be nouns or noun phrases. The actions (verbs) are captured by the causal links connecting the variables. A causal diagram captures the structure of the system, not its behaviour. [9]

Sterman states that selected names for which the meaning of an increase or decrease is clear, variables that can be larger or smaller. Without a clear sense of direction for the variables you will not be able to assign meaningful link polarities. Variable names should be chosen so their normal sense of direction is positive. [9]

Table 2. Model variables

Nr	Variable	Abbr.
1	Customer Satisfaction	CUS
2	Order Quantity and Demand	ORD
3	On Time Delivery	OTD
4	Price (Cost)	PRI
5	Product Conformity – Quality	QUA
6	Imported Raw Material	IMP
7	Planning Capability	PLA
8	Financial Capability	FIN
9	Machinery, Equipment, Tools and Testing Capability	MET
10	Qualified Staff	STA
11	Geographical Location Advantage	GEO
12	Supplier and Subcontractor Development	SUP
13	Production Quality	PCV
14	Leadership and Policies	POL
15	Conforming Product	NCP
16	Offset Provision	OFF
17	Personnel Turnover	PER
18	Design Capability	DES
19	Production Quantity	PRO

Interviews are almost never sufficient alone and must be supplemented by other sources of data both qualitative and quantitative. People have only a local partial understanding of the system so you must interview all relevant actors at multiple levels

including outside the organization (customers, suppliers etc.) [9]

Interviewed organizations and sector specialists are selected from both Aerospace and also defense organizations. Three of these companies are major frame manufacturers, one is public organization, rest of them are Tier 1 – 2 suppliers of the sectors. Conformity assessment experts are involved.

Other experts are from quality and supply processes and design and development specialists etc. Levels from top management to operational are involved in interviews. A conceptual model has been developed by the information collected during interviews.

Additional survey study conducted with sector suppliers and organizations to verify the data collected during interview phase and to determined and analyze the weights of determined variables as reinforcing or balancing.

During the survey study, survey has been sent to 260 collectors. 52 responses received, and overall % 20 collection performance achieved.

42 of the 52 responders are implementing AS 9100 series quality management system standards other 7 are implementing ISO 9001 quality management system standard.

Below is illustration of data collection methodology for the study.

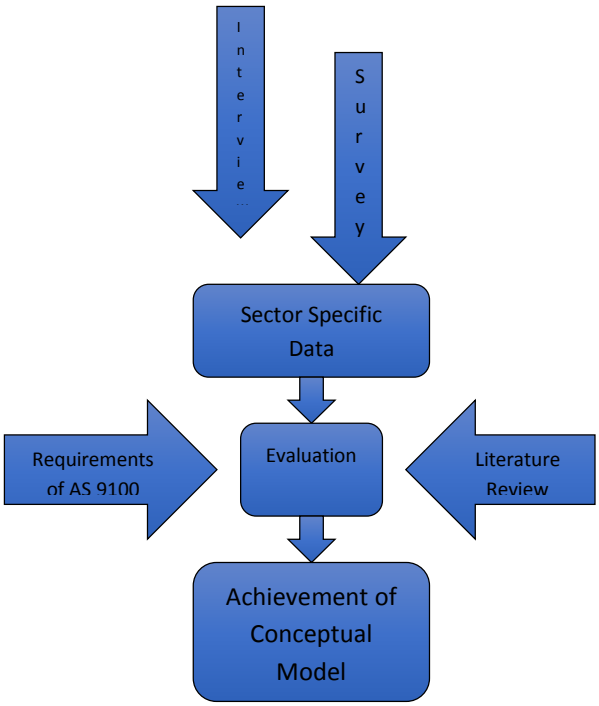

Figure 6. Data collection methodology

Survey has been designed by using 7 point Likert Scale. Scale is defining balancing effects from 1 to 3. Neutral effect at 4 and reinforcing effects from 4 to 7. Below is the qualitative definition in the survey parameters.

Table 3. Likert Scale used in survey and explanations

(1)Very High Balancing Effect	(2) High Balancing Effect	(3) Balancing Effect
(4) Neutral Effect		
(5) Reinforcing Effect	(6) High Reinforcing Effect	(7) Very High Reinforcing Effect

4. Results of on-site studies and discussions of variables

Results collected from surveys have been analyzed. Average of the overall responses on a single question on effects of one variable to other is calculated and below table is prepared. This table will be used for determination of polarity of arrows during achievement of causal loop diagram.

Table 4a. Results of survey and explanations of effects.

Nr	Affecting Variable	Affected Variable	Weight	Effect Type
1	QUA	CUS	6,08	R
2	PCV	NCP	6,03	R
3	OTD	CUS	6	R
4	PLA	OTD	5,96	R
5	QUA	ORD	5,94	R
6	CUS	ORD	5,71	R
7	OTD	ORD	5,67	R
8	ORD	PRO	5,63	R
9	MET	PLA	5,59	R
10	MET	PCV	5,57	R
11	CUS	POL	5,52	R

Table 5b. Results of survey and explanations of effects.

Nr	Affecting Variable	Affected Variable	Weight	Effect Type
12	MET	DES	5,31	R
13	ORD	FIN	5,2	R
14	DES	ORD	5,2	R
15	IMP	PRI	5,1	R
16	FIN	MET	5,06	R
17	PRO	PCV	5	R
18	QUA	OFF	4,94	R
19	DES	OFF	4,84	R
20	OFF	FIN	4,82	R
21	PRI	FIN	4,8	R
22	POL	OFF	4,68	R
23	POL	IMP	4,65	R
24	OFF	ORD	4,6	R
25	SUP	PLA	4,52	R
26	FIN	GEO	4,44	R
27	STA	PRI	4,44	R
28	MET	PRI	4,4	R
29	ORD	QUA	4,24	R
30	GEO	SUP	4,18	R
31	GEO	STA	4,1	R
32	IMP	PCV	4,45	R
33	ORD	OTD	3,85	B
34	ORD	PRI	3,63	B
35	PRI	ORD	3,12	B
36	PRI	CUS	3,08	B
37	IMP	PLA	3	B
38	FIN	PER	2,92	B
39	NCP	QUA	2,12	B
40	PER	STA	2,02	B

Subsections of this part will discuss these relations and effects as well relevancy and support of standard on these concepts.

4.1 Customer Satisfaction (CUS)

AS 9100 standard Clause 8.2 (p38) states the organization shall monitor customers' perceptions of the degree to which their needs and expectations have been fulfilled. Information to be monitored and used for the evaluation of customer satisfaction shall include, but is not limited to, product and service conformity, on-time delivery performance, customer complaints, and corrective action requests. The organization shall develop and implement plans for customer satisfaction improvement that address deficiencies identified by these evaluations and assess the effectiveness of the results [12].

Table 6. Effects and Weights on Customer Satisfaction

Affecting Variable	Affected Variable	Weight	Effect Type
QUA	CUS	6,08	R
OTD	CUS	6	R
PRI	CUS	3,08	B

Table 5 depicts that for customer most important issue is to have correct and conforming product. Having this product on time is also very important and has a high-very high reinforcing effect on customer satisfaction. Price increase has a balancing effect on customer satisfaction however this balancing effect is not high or very high. This result depicts that aerospace and defense sector is not very sensitive to price increases. Customer can accept higher prices in case product quality and on time delivery assured.

4.2 Order quantity and Demand (ORD)

Order quantity (ORD) has a critical role in supplier customer relations in Turkish Industry. There are suppliers that are already serving in many industries that are satisfying the needs of customers. However newly developing aerospace defense sector demand not always achieving critical mass that will reach to a quick break-even point. Turkish industry is highly dependent on order quantity. Long-term agreements are in place to provide a basis for the supplier for future planning. Order quantity is also important for determination of production methods. In cases where order quantity is sufficient, suppliers are choosing more stable and reliable manufacturing methods.

Site visits and interview with the experts presented that there is a meaningful relation between product quality, customer satisfaction, on time delivery and order quantity. Provided that product quality, customer satisfaction and on time delivery are

established suppliers will have more orders. Design capable organizations will have more orders and offset contracts will also affect the order quantity. While price has an effect on order quantity it is not as effective as other parameters.

Table 7. Effects and Weights on Order Quantity

Affecting Variable	Affected Variable	Weight	Effect Type
QUA	ORD	5,94	R
CUS	ORD	5,71	R
OTD	ORD	5,67	R
DES	ORD	5,2	R
OFF	ORD	4,6	R
PRI	ORD	3,12	B

4.3 On Time Delivery (OTD)

On time delivery is a crucial process performance indicator in aerospace and defense supply chain. This indicator is monitored internally by organizations as required by AS 9100 and also monitored by the customers using various tools including score cards. On time delivery performance of the supplier is used for grading and classification (green, yellow, red, gold, silver etc.). There are penalty clauses in basic order agreements. Suppliers shall implement procedures for planning activities and risks involved in product realization that threatens on time delivery.

AS 9100 standard Clause 8.1 (p21) states that the organization shall plan, implement, and control the processes (see 4.4) needed to meet the requirements for the provision of products and services. Same clause article c requires organization to determine the resources needed to achieve conformity to the product and service requirements and to meet on-time delivery of products and services. [12]

Considering the demand of sector and production schedules of the customers suppliers shall be consistent and achieve high performance results of on time delivery. Boeing has planned by outsourcing 70% of the development and production activities under the 787 program which resulted in project delays. Boeing planned to shorten the development time by leveraging suppliers' ability to develop different parts at the same time. Boeing is relying on its tier-1 global strategic partners to develop and build entire sections of the Dreamliner that are based on unproven technology. Any break in the supply chain can cause significant delays of the overall production [16]. Project delays and production delays is also a concern for various projects of Turkey. On-time delivery performance is reinforced by order quantity as shown in Figure 4. This reinforcing effect is only possible if an effective management system operating background. Management system includes project and production planning activities including operational risk management. On time delivery of a supplier is widely reinforced by planning capability of the supplier, which includes production planning, and project management activities.

Table 8. Effects and Weights on On Time Delivery

Affecting Variable	Affected Variable	Weight	Effect Type
PLA	OTD	5,96	R
ORD	OTD	3,85	B
OTD	CUS	6	R
OTD	ORD	5,67	R

4.4 Price (Cost) (PRI)

AS 9100, "Quality Management Systems – Requirements for Aviation, Space, and Defense Organizations": standardizes quality management system requirements to the greatest extent possible and can be used at all levels of the supply chain by organizations around the world. Its use should result in improved quality, cost, and delivery performance through the reduction or elimination of organization-unique requirements, effective implementation of the quality management system, and wider application of good practice. [12].

Aerospace and defense sector products costs structure is normally high, based on below factors;

- Risk engaged in the products
- Requirement of qualified staff
- Requirements of special processes
- Investment on machinery and equipment
- Requirements of specific tests for airworthiness
- Raw materials
- Order amounts are lower that other sectors

These factors are forcing suppliers to engage more indirect costs, as well as direct costs on unit

products. Although decrease of costs are one of the expectations from the implementation of the standard, this is more relevant to process improvement. Beside cost improvement Product safety is a more important concern of the industry. Survey study confirmed the above discussed on costs. It also stated that for Turkey's specific position imported raw materials have an high effect on costs. Surveys also verified that increase on order quantity will have a balancing effect on the Price.

Table 9. Effects and Weights on Price

Affecting Variable	Affected Variable	Weight	Effect Type
IMP	PRI	5,1	R
STA	PRI	4,44	R
MET	PRI	4,4	R
ORD	PRI	3,63	B

4.5 Product Conformity - Quality (QUA)

Results depicted on Table 9 confirm that Product conformity and quality increases when order quantity increases. This issue can be interpreted as doing more product improves process stability and once the process is capable it can be sustained to conform the requirements. Product quality is highly balanced nonconforming products resulting from production processes.

Table 10. Effects and Weights for Product Quality

Affecting Variable	Affected Variable	Weight	Effect Type
ORD	QUA	4,24	R
NCP	QUA	2,12	B

4.6 Imported Raw Material (IMP)

Study determined that level of imported raw material used in the sector is mostly affecting prices and customer satisfaction. Turkey is an importer for major material, components and parts used in metal processing (ie. Aluminum.), composite manufacturing, electrical, electronic and avionic sectors. It is also verified that Turkey needs to establish policies on governmental and sectorial level to improve the local sources.

Table 11. Effects and Weights for Imported Raw Material

Affecting Variable	Affected Variable	Weight	Effect Type
POL	IMP	4,65	R

4.7 Planning Capability (Production and Project Management) (PLA)

AS 9100 Clause 8.1 when referring to Project Management also states that as appropriate to the organization, customer requirements, and products and services, the organization shall plan and manage product and service provision in a structured and controlled manner including scheduled events performed in a planned sequence to meet requirements at acceptable risk, within resource and schedule constraints. [12]. Planning is an important component of PDCA cycle (see **Figure 3.** Representation of the structure of AS 9100:2016 Standard in the PDCA cycle). Planning capability of an organization is highly reinforced by machinery, equipment, tool and testing capability as well as the supply chain development.

Table 12. Effects and Weights for Plan Capability

Affecting Variable	Affected Variable	Weight	Effect Type
MET	PLA	5,59	R
SUP	PLA	4,52	R
IMP	PLA	3	B

4.8 Financial Capability (FIN)

AS 9100 standard Clause 7.1.1 is relevant to resources. This clause (p18) requires that the organization shall determine and provide the resources needed for the establishment, implementation, maintenance, and continual improvement of the quality management system [12].

Table 13. Effects and Weights for Financial Capability

Affecting Variable	Affected Variable	Weight	Effect Type
ORD	FIN	5,2	R
OFF	FIN	4,82	R
PRI	FIN	4,8	R

Study verified that financial capability of an organization mostly relevant to order quantity. Major clients are supporting the suppliers by establishing long term basic order agreements (BOA) in Turkey. Suppliers may use these long-term agreements ie 5 years or predefined quantities) to improve cash flow and funding through banks as well. Direct sales to international major players. Direct export and sales to global players is an opportunity to improve sales performance. Turkish suppliers are improving capabilities to be listed in global supplier lists.

4.9 Machinery, Equipment, Tools and Testing Capability (MET)

AS 9100 standard Clause 7.1.3 and 7.1.5 are relevant to these resources. 7.1.3 clause (p17) requires that The organization shall determine, provide, and maintain the infrastructure necessary for the operation of its processes and to achieve conformity of products and services. This includes equipment, including hardware and software; and 7.1.5 clause (p17) also requires The organization shall determine and provide the resources needed to ensure valid and reliable results when monitoring or measuring is used to verify the conformity of products and services to requirements [12].

Table 14. Effects and Weights for Machinery, Equipment, Tools and Testing Capability

Affecting Variable	Affected Variable	Weight	Effect Type
FIN	MET	5,06	R

Financial capability of an organization has an high reinforcing effect for improving machinery and equipment, tool and testing infrastructure. Testing infrastructure on sectorial level is getting more important. Suppliers are facing difficulties on finding competent test centers locally. Fire safety tests at approved labs (such as EASA), dynamic testing for aerospace etc. are supplied only by foreign sources. Machinery and equipment suppliers in some sectors (ie. metal processing, avionics, electronics) are again mostly imported.

4.10 Qualified Staff (STA)

Most quality information about aviation products is pre-served and delivered in writing, which is relatively inconvenient to use and look up. This inhibits the sharing and analysis of quality information among employees. In addition, these aviation firms face a serious lack of professional employees who are proficient in the use of fundamental quantitative analysis tools. At present, quality information is not effectively used in daily production decision-making processes [28].

AS 9100 standard Clause 7.2 requires that organization determine the necessary competence of person(s) doing work under its control that affects the performance and effectiveness of the quality management system; and ensure that these persons are competent on the basis of appropriate education, training, or experience [12].

Table 15. Effects and Weights Qualified Staff

Affecting Variable	Affected Variable	Weight	Effect Type
GEO	STA	4,1	R
PER	STA	2,02	B

Turkish suppliers are having difficulties on finding qualified staff. Survey results determined that geographical advantage almost has a neutral but still a reinforcing effect on staff. It has to be considered that current aerospace and defense suppliers are already located at these more advantageous areas.

4.11 Geographical Location Advantage (GEO)

Turkey has established various clusters of aerospace and defense industry suppliers around major manufacturers. Ankara and Eskişehir are main centers for the sector. Istanbul, İzmir, Bursa and some other cities have initiatives for establishment of new clusters. Current major manufacturers like TAI are establishing supplier development zones near their sites. This approach is similar to global players and will improve Turkey's capacity. Clusters will support supply chain on shipment advantages, legal requirements compliance and ease of communication with clients and information exchange. Organizations are also achieving purchasing and supply advantage when operating in these environment. Table 15 has defined that financial capability of an organization will have an reinforcing effect on being located in a location that is geographically advantageous. However this effect is rather limited. This may be the result of current locations of supply chain which are mainly located

at the cities Istanbul, Ankara and Eskişehir. See Figure 7 for location distribution of AS 9100 certified suppliers.

Table 16. Effects and Weights for Geographical Location Advantage

Affecting Variable	Affected Variable	Weight	Effect Type
FIN	GEO	4,44	R

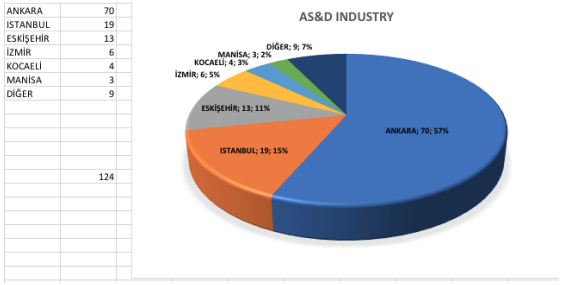

Figure 7. location distribution of AS 9100 certified suppliers. (May 2018)

4.12 Supplier and Subcontractor Development (SUP)

AS 9100 standard Clause 8.4.1 is relevant to supplier management. In accordance with this clause (p28) the organization shall determine and apply criteria for the evaluation, selection, monitoring of performance, and re-evaluation of external providers, based on their ability to provide processes or products and services in accordance with requirements [12].

Organizations are having problems on supply chain development. These problems mostly more evident on special processes suppliers. Special processes are processes where the resulting output cannot be verified by subsequent monitoring or measurement. Samples of special processes are (plating, welding, painting, NDT etc.) Special processes are highly used in the sector and qualified by various methods such as customer source approval (ie Boeing approved source) or 3rd party approved sources (ie NADCAP)

Surveys verified that being located in geographically advantageous area will reinforce the supply chain improvement. This effect is rather determined limited.

Table 17. Effects and Weights for Supplier and Subcontractor Development

Affecting Variable	Affected Variable	Weight	Effect Type
GEO	SUP	4,18	R

4.13 Production Quality (PCV)

Process variations that are affecting production quality shall be minimized. As a result of learning effect of producing more and recurring expertise will be increasing the number and rate of conforming products which are reinforcing product quality.

AS 9100 Clause 8.1 (pg 21) requires that the organization shall implement production process verification activities to ensure the production process is able to produce products that meet requirements.

Same clause refers that these activities can include risk assessments, capacity studies, capability studies, and control plans. ensuring that when sampling is used as a means of product acceptance, the sampling plan is justified on the basis of recognized statistical principles and appropriate for use (i.e., matching the sampling plan to the criticality of the product and to the process capability).

Survey studies presented that imported raw materials, production quantity and machinery equipment and tools, testing will balance the process variations.

When process variations are balanced (decreased) product quality will reinforced. It is also evident that staff qualification will be balancing process variations.

Table 18. Effects and Weights for Process Variation

Affecting Variable	Affected Variable	Weight	Effect Type
IMP	PCV	4,45	R
PRO	PCV	5,00	R
MET	PCV	5,57	R

4.14 Leadership and Policies (POL)

Leadership and policies have significant effect on successful implementation of the system. This can be considered under two topics. External policies and leadership such as public policies, organization of industry clusters and sector specific initiatives. Internal policy, objectives and leadership that enforces internal processes, improvement of culture in the organization and enabling effective system implementation.

AS 9100 standard Clause 5 also requires that top management shall demonstrate leadership and commitment with respect to the quality management system. Clause 4.1 is relevant to context of the organization. In accordance with this clause (p11) the organization shall determine external and internal issues that are relevant to its purpose and its strategic direction and that affect its ability to achieve the intended result(s) of its quality management system. Same clause also notes that understanding the external context can be facilitated by considering issues arising from legal, technological, competitive market, cultural, social, and economic environment, whether international, national, regional, or local [12].

Table 19.Effects and Weights for Leadership and Policies

Affecting Variable	Affected Variable	Weight	Effect Type
CUS	POL	5,52	R

Considering the policies are within internal context organizations policy on operating at aerospace and defense sector is highly reinforced by customer satisfaction. However, if considered under external context Turkey's policies on development of aerospace and defense and industry is an Exogenous variable that is out of the control of organization.

4.15 Conforming Product (NCP)

AS 9100 standard Clause 8.7 is relevant to control of nonconforming output. This clause (p36) requires that the organization shall ensure that outputs that do not conform to their requirements are identified and controlled to prevent their unintended use or delivery [12].

Table 20. Effects and Weights for Nonconforming Product

Affecting Variable	Affected Variable	Weight	Effect Type
PCV	NCP	5,33	R

Conforming products are highly reinforced by production quality. When discussing nonconforming products sector shall not only understand products out of specifications. Aerospace and defense industry is improving controls on counterfeitparts and positively affects awareness on this topic.

Counterfeit Part is an unauthorized copy, imitation, substitute, or modified part (e.g., material, part, component), which is knowingly misrepresented as a specified genuine part of an original or authorized manufacturer. Examples of a counterfeit part can include, but are not limited to, the false identification of marking or labeling, grade, serial number, date code, documentation, or performance characteristics. [12]

4.16 Offset Provision (OFF)

Turkey is an importer of aerospace and defense final products such as aircrafts, sea and ground platforms and defense systems. Undersecretary of Defense Industry and companies like Turkish Airlines, are involved in this import activity.

Offset is defined as the activities conducted to improve Turkey's production capabilities and market share and/or competitiveness in international market and reducing balance of payment deficits in the context of supply of defense requirements. Following are considered as offset; export of defense products and services, increase the share of local net value added on supply contracts, technological cooperation, investment and R&D activities. [7].

When summarized Turkish suppliers are taking roles on producing parts, components, systems and subsystems of imported aerospace defense products. Survey has verified that in order to get these contracts industry needs to improve product quality. Being capable of design and Turkey's overall policies will also have reinforcing effect on offset based contract awards for suppliers.

Table 21. Effects and Weights for Offset Provision

Affecting Variable	Affected Variable	Weight	Effect Type
QUA	OFF	4,94	R
DES	OFF	4,84	R
POL	OFF	4,68	R

4.17 Personnel Turnover (PER)

AS 9100 standard clause 7.1.2 is relevant to human resource management. This clause (p17) requires that the organization shall determine and provide the persons necessary for the effective implementation of its quality management system and for the operation and control of its processes [12]. Keeping qualified staff is important for organizations and as the financial performance of an organization increased personnel turnover is balanced as the economic conditions provided to employees are improved. Personnel turnover is important parameters for control of human factor-based errors as well as ethical behavior exposed by standards

Table 22. Effects and Weights for Personnel Turnover

Affecting Variable	Affected Variable	Weight	Effect Type
FIN	PER	2,92	B

4.18 Design Capability (DES)

Design capability is an important tool for success in aerospace and defense industry. Design activities in aerospace industry are also under regulatory control.

Type certificate holder and design organizations are the core responsible organizations to adopt and approve every item and or change in an aircraft which mainly opens the way for improving relevant industries and supply chain as well.

Being involved in the design process is a critical topic for organizations to achieve satisfactory organizational performance as well as achieving a consistent industry structure. Robust design examples of Boeing 737, Airbus 320 passenger aircrafts or C47 Dakota cargo aircraft has achieved decades of service years and thousands of productions with incremental improvement and innovations. In Turkey organizations are supported by incentives of government as establishing their Research and Development Centers which is leading to development of local technologies. AS 9100 standard Clause 8.3 is relevant to design process. This clause (p25) states that the organization shall establish, implement, and maintain a design and development process that is appropriate to ensure the subsequent provision of products and services. Process from planning, to implementation stages (input, outputs, verification, validation review, changes) subject to this clause [12].

Table 23. Effects and Weights for Design Capability

Affecting Variable	Affected Variable	Weight	Effect Type
MET	DES	5,31	R

Survey has verified that machinery, equipment (design software and tools) infrastructure is highly reinforcing design capabilities. It is also considered that qualified staff will improved the design capability. However this was not visible during interviews and discussions. This is an implication of the need for improvement in this area and top management shall be more committed to the development of manpower in the design process.

4.19 Production Quantity (PRO)

Critical mass concept is important for setting up a organization capable and sustainable. Order quantity has an high reinforcing effect on production quantity which will lead to balance process variations and increase product quality. Quantities and amounts are currently not reaching critical mass in Turkish organizations and numbers are to be increased.

Table 24 Effects and Weights for Production Quantity

Affecting Variable	Affected Variable	Weight	Effect Type
ORD	PRO	5,63	R

5. Causal Loops

Causal loop diagrams (CLDs) are an important tool for representing the feedback structure of systems. Long used in academic work, and increasingly common in business, CLDs are excellent for

- Quickly capturing your hypotheses about the causes of

dynamics;
- Eliciting and capturing the mental models of individuals or teams;
- Communicating the important feedbacks you believe are responsible for a problem.

The conventions for drawing causal diagrams are simple but should be followed faithfully. [9]

Link polarities describe the structure of the system. They do not describe the behavior of the variables. That is, they describe what would happen IF there were a change. They do not describe what actually happens. To determine what actually happens you need to know how all the inputs are changing. [9]

When assessing the polarity of individual links, assume all other variables are constant (the famous assumption of ceteris paribus) [9]

Causal loop diagram will take customer satisfaction as the focal point and clarify the relationship with other variables. Based on this general relation ship field studies are detailed to define which other variables will be effecting these core variables. Data entry to VENSIM software will lead to visualization of causal loops between the variables.

Customer is most important interested party in a trade relation for a profit organization. [11] ISO 9004 states needs and expectations of a customer as on time delivery of product (OTD), conformity of product (QUA) with acceptable pricing (PRI). Cause and loop model of this study do not directly links these variables but adds another variable in between. Sterman confirms this action by stating that separating links with apparently ambiguous polarity into the underlying multiple pathways is a fruitful method to deepen your understanding of the causal structure, delays, and behavior of the system. [9] Variable that links these variables is order quantity (ORD) and determines that increasing level of customer satisfaction will lead to increase order quantity from customer to the supplier. Delays are critical in creating dynamics. Delays give systems inertia, can create oscillations, and are often responsible for trade-offs between the short- and long-run effects of policies. Your causal diagrams should include delays that are important to the dynamic hypothesis or significant relative to your time horizon. [9] Our model also defines various delays in relations which explains the implementation time and maturity of the system.

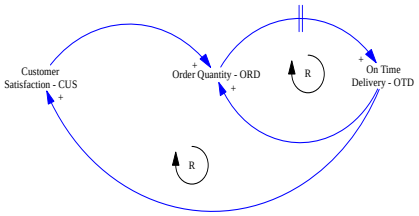

Figure 8. Cause and Loop Diagram (CUS-ORD-OTD)

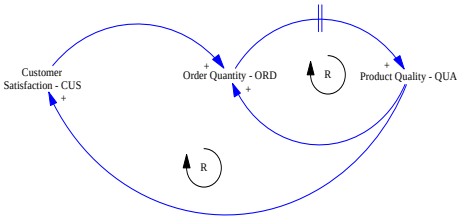

Figure 9. Cause and Loop Diagram (CUS-ORD-QUA)

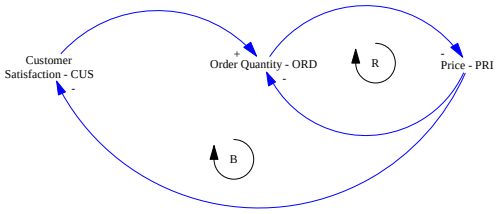

Figure 10 Cause and Loop Diagram (CUS-ORD-PRI)

Based on relations defined through surveys and effects. Figure 10 provides overall Cause and Loop Model. Figure 13 illustrates Quality Loop. Figure 14 illustrates On time Delivery Loop and Figure 15 illustrates Price Loop.

To maximize the clarity and impact of your causal diagrams, you should follow some basic principles of graphic design.

1. Use curved lines for information feedbacks. Curved lines help the reader visualize the feedback loops.

2. Make important loops follow circular or oval paths.

3. Organize your diagrams to minimize crossed lines.

4. Don't put circles, hexagons, or other symbols around the variables in causal diagrams. Symbols without meaning are "chart junk" and serve only to clutter and distract. An exception: You will often need to make the stock and flow structure of a system explicit in your diagrams.

In these cases the rectangles and valves around the variables tell the reader which are stocks and which are flows-they convey important information

5. Iterate. Since you often won't know what all the variables and loops will be when you start, you will have to redraw your diagrams, often many times, to find the best layout. [9]

Presenting a complex causal map all at once makes it hard to see the loops, understand which are important, or understand how they generate the dynamics. Resist the temptation to put all the loops you and your clients have identified into a single comprehensive diagram. Build up your model in stages, with a series of smaller causal loop diagrams. [9]

To simplify the Model Merging Similar Variables and Eliminating neutral effect variables iterations are used. Almost neutral effect variable such as GEO (Geographical location) removed from the model .

Similar variables such as manpower, finance and machinery are merged under the name of Resources (Availability)

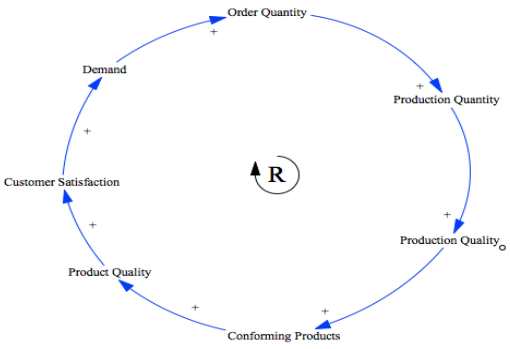

Figure 11. Quality Loop

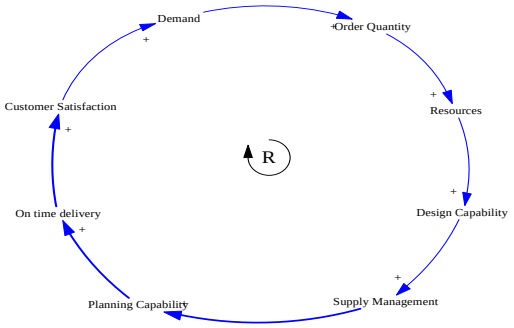

Figure 12 Ontime Delivery Loop

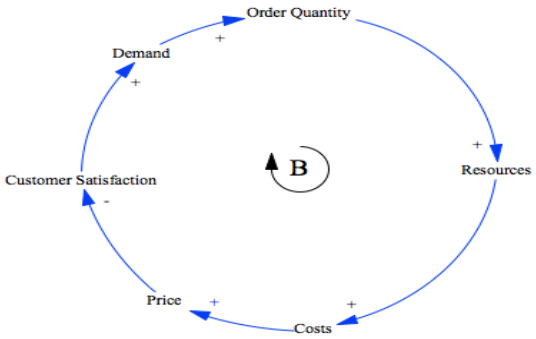

Figure 13. Price Loop

On time delivery, quality and price loops are merged to achieve the final overall causal loop diagram given in Figure 14.

6. Validation of Model

Sterman states that system Dynamics models cannot be perfectly validated. It may be impossible to create a perfect model that is perfectly valid [9].

Validation is the process of establishing confidence in the soundness and useful-ness of a model. Validation begins as the model builder accumulates confidence that a model behaves plausibly and generates problem symptoms or modes of behavior seen in the real system. Validation then extends to include persons not directly involved in constructing the model. [34]
While conforming this Burns and Musa states that some models are wrong more frequently than others (page 2) Burns and Musa evaluates the models by following criteria; [8]

- Clarity
- Quantity existence and units associated therewith

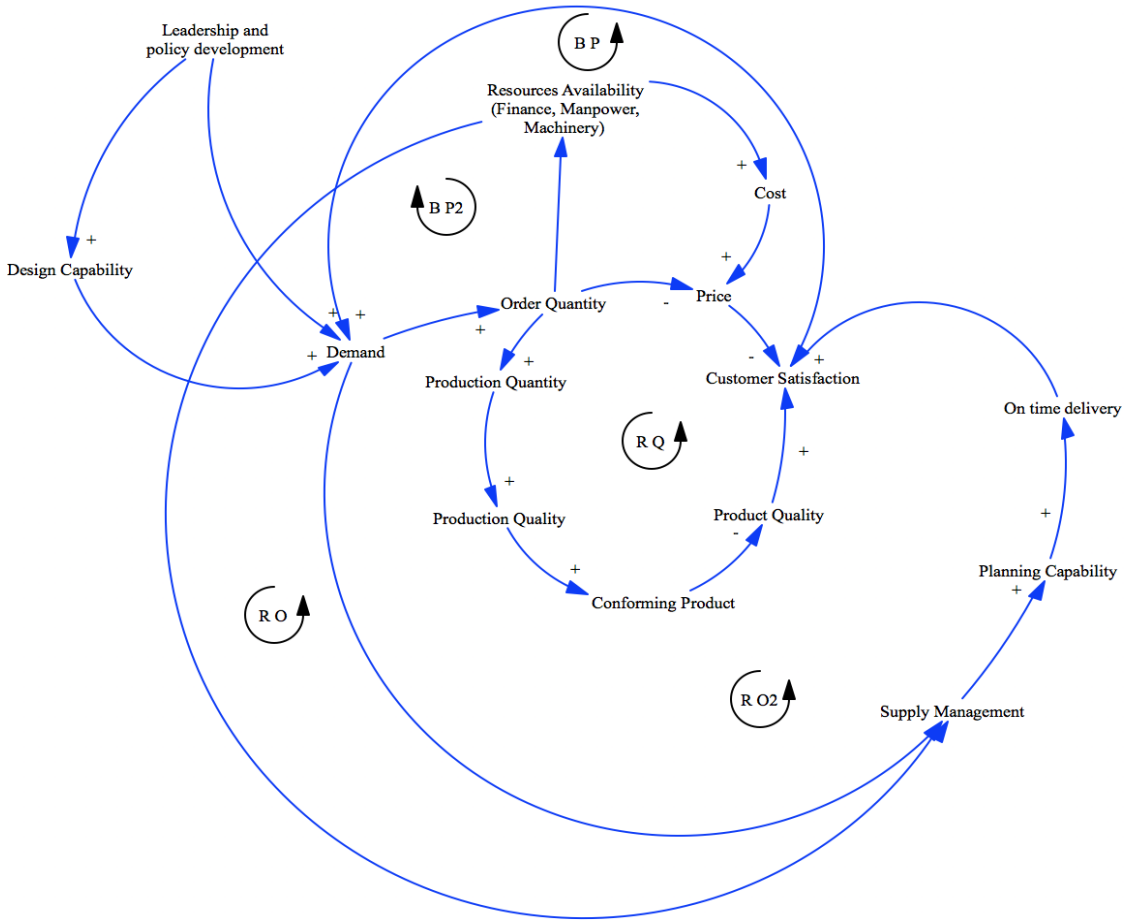

Figure 14 Overall Causal Loop Model

- Causality existence
- Cause insufficiency
- Additional cause
- Cause effect reversal
- Predicted effect existence
- Tautology
- Leaps of Faith

Approaches and objectives are diverse enough that not all of the tests proposed in the literature are applicable to each modeling Project. It seems that it would be helpful to bin these tests to make it easier for modelers to identify the best subset of tests for each project. It is clear that the decision as to whether or not a particular test is appropriate should consider the assumed basis for model truth, or correctness. [33]

Five components of modeling practice are defined as;

- Systems mapping
- Quantititative modelling
- Hypothesis testing
- Uncertainty analysis
- Forecasting optimization [33]

At the stage of Systems mapping; suggested validation methods are a. face validity (structural assessment through deductive process) and relevant question is if the model structure consistent with relevant descriptive knowledge of the system? And b. validity of decision rules (structural focus) and relevant question is Do the decision rules capture the

behavior of the actors in the system? [33] This study is focused on Causal loop mapping of a quality management system and stay at the stage of systems mapping. Following answers are available fort he validation questions;

1. Is the model structure consistent with relevant descriptive knowledge of the system?

The system structure is defined by internationally accepted quality management system standard. This standard provides basis for expectations from the system. These expectations are validated by interviews conducted by sector specialist and companies that are implementing this standard. Findings and structure of the model is also validated by survey study conducted at organizations. Based on this information answer is Yes, model structure is consistent with relevant descriptive knowledge of the system.

2. Do the decision rules capture the behavior of the actors in the system?

Decision rules relations and polarities are directly captured thorugh a survey study conducted at the suppliers of the aerospace and defense industry. Answers do not Show wide variety and verified that these are current most appropriate actors of the sector and Yes rules capture the behavior of the actors in the system. Based on this scenario, study and causal loop model has generated valid results.

7. Results

Turkey's aerospace and defense supply chain and relevant organizations have improvement areas in following fields;

7.1 Human resources;

Human resources is an important asset for Aerospace and defense sector. Awareness of staff on systems thinking, product safety culture and reduction of errors by controlling Human Factors including improvement on awareness of ethical behavior is generated long term and provide a good basis for aware staff with improved competence.

Personnel turnover rate shall be reduced in sector. Qualified staff has to be employed and kept for long term.

This will improve sustainable product quality and establish conformity with customer requirements.

7.2 Supply and Procurement

Domestic supply chain has to be improved focusing on special processes and local provision of raw materials. Turkey has to consider purchasing higher quantities of raw materials to be procured with better lead times. Critical materials shall be produced internally. Supply is also considered for machinery and equipment, tools. Supply chain improvement is critical for special process suppliers. OEM's and Tier 1 suppliers shall consider approving suppliers and special process sources and support them with process specifications and process, product audits. In some cases raw material directly supplied by the customer which prevents material based quality problems. This is more visible in the machining suppliers and provides a more controlled area prevents counterfeit parts involvement and enhances product safety.

7.3 Design Capability

Design owners and Type certificate holders for aerospace and defense products have a deep background and information on products, materials used and operational performance. This information is crucial to flow down and improve supply chain with product performance. Design capability will also increase the quantities required from supply chain which, will improve investments and financial capabilities. Design capability will also positively affect the offset allocation. Number of Design Organizations are to be improved which may approve design works and changes on already certified articles. Platform owners such as TAI, BAYKAR, ROKETSAN, ASELSAN etc. will pave the way for supply chain.

7.4 Cluster Structure, Capacity Utilization Improvement

Suppliers can be better organized with supply clusters and zones. This will improve communication, information exchange, capacity planning and utilization. Suppliers are mainly lacking of adequate quantities of orders that will provide stability. Security of mission critical information will be provided. Allocating human resources and manpower will be easier.

7.5 Testing, verification and validation infrastructure

Sector requires specific testing, verification and

validation infrastructure. Critical dynamic safety tests, fire safety tests, electromagnetic compatibility tests are conducted by approved sources abroad. These approved sources has to be developed locally and or better accessible by the stakeholders. Current laboratories and infrastructure can be approved and accredited by authorities.

7.6 Order Quantity and Financial Support

Considering the scale economy, Turkish suppliers are facing issues for planning and new investments as order quantities are rather less in the industry. Quantities and flow of business do not result in a long term financial stability of the supplier. They are being supported by basic order agreements (BOA) by OEM's and Tier 1 suppliers. These agreements paves the way and even increases the credibility of the suppliers. As demand and order quantity do not reach to a critical mass industry supply chain mainly cannot support bigger and financially stronger suppliers. Structure cannot be attractive for the others ie. Automotive suppliers. However, this structure supports flexibility and in mid-term Turkey has an opportunity to achieve a supply chain structure specific to AS&D that can serve and export to international AS&D markets. Tier 1 suppliers have already established these relations in many cases and are listed in supplier lists of international OEM's.

8. Conclusions

Sustainability of on time delivery and quality in a supply chain with acceptable price level is a must for aerospace and defense manufacturers. Order schedules are tight, manufacturing lines idle times are very low and manufacturing sequence do not let supply delays. Same is applicable for quality failures which will result in band delays, safety and performance issues for manufacturing. Delays, quality and performance issues result in high amounts of financial losses and penalties, as contract enforcements are so high. Supplier effective quality management systems are essential for enhancing on time delivery and product conformity. However whatever the implementation level is systems are dynamic structures and feedback effects are available within time frames. This study proposes a causal loop diagram of quality management system implementation and validates the model with a set of criteria. Study also derives that system requirements are correctly defined and will lead supply chain for inevitable improvement when well understood and implemented. One of the study outputs show that Human Factor in system approach is one of the most critical issues, also depending on cultural differences in supply chain. Safety and aviation culture improvement in Turkish companies for better understanding results of performance issues in their work which may lead quality and delivery failures as well as safety issues. Causal Loop technique generates the model while variables are explained with cross reference standard requirements. Future research could improve by using quantified data on variables and determined the effect of implementation of the system on organizations performance to improve customer satisfaction. This study is expected to generate the results leading to a goal seeking model and considering a time horizon to 3 years which is a one certification cycle, high level of customer satisfaction in theory % 100 can be achieved.

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