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Interrelationships between product quality and different demand cases in ramp-up scenarios

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Abstract

The following paper presents an approach to enable companies to cope with the interdependencies between product quality and different demand scenarios. Although, companies strive to enhance their quality and demand policies they lack a holistic view of these parameters. Thus, the aim of the paper is to determine the impact of the chosen quality and demand policy on the availability of the goods. In a simulation setup, different demand and quality policies have been analysed by using a Design of Experiments approach. In a first step minimum stock levels have been varied to verify the significance of the simulation. In a second step error rate has been increased to identify the impact on the availability of the goods. In particular, considering the quality and demand policy within ramp-up cases plays an important to guarantee the ability to supply.

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1. Introduction

Nowadays, companies are facing a wide range of challenges in the field of customer demand, dynamic environment conditions and quality problems (Schuh, *et al.*, 2011). Companies have to adapt themselves and their processes to dynamic environment conditions like movements in customer demand, reschedules in supply as well as turbulences in networks (Brosze, *et. al.*, 2010). Therefore, companies invest time for the planning of the supply chain as well as the planning of quality policies without knowing the impact of ones decision on the other factor. If companies knew ahead what consequences of a particular choice, results will be, that knowledge helps to reduce the planning complexity and increases the availability of their goods. In particular, these findings are of importance for the machinery and plant engineering industry since due to the small quantities every production is connected to a ramp-up scenario. Hence, the knowledge of the right quality and demand policy plays an important role for these companies to ensure the ability to supply.

Within the Cluster of Excellence (CoE) on “Integrative Production Technology for High-Wage Countries” several institutes at RWTH Aachen University are conducting research on fundamentals of a sustainable production strategy. As part of the CoE on “Integrative Production Technology for High-Wage Countries” the sub-project D-1 aims at the goal of developing a self-optimising production network. By applying instruments of self-optimisation it leads to a quicker achievement of an optimal working point under changing input-parameters. Within the scope of the research project the inter-company material and information flow is investigated which includes the leverage of the quality management and diverse other parameters on the supply chain.

In the first part of the paper an overview of the simulation and the setup is given. The methodological approach of system dynamics is outlined in the second chapter. Chapter three discusses the obtained results of the experiments. Four

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different scenarios have been carried out to indetify the interactions between inventory and quality policies. Chapter six draws together the main findings of the paper.

2. Methodological Approach and Preconditions

By using a system-oriented approach based on system dynamics, a supply chain model is designed. System Dynamics has been deleloped by Jay W. Forrester at the Massachusetts Institute of Technology and provides a modelling methodology for understanding and representing the behaviour of complex systems (Forrester, 1961). The methodology of system dynamics finds it origin in cybernetics and is based on methods of the control theory, decision theory and different simulation technologies (Schröter, 2006). It deals with the interactions between different components of a system and focuses on the feedback between these variables. An essential part of system dynamics is the focus on feedback that enables a more holistic view of the real world. System dynamics models have been used to describe a wide range of problems, e.g. climate change, population growth, water resources and industrial systems (Sterman, 2000).

3. Experimental Setup of the Supply Chain

At the Institute for Industrial Management (FIR) at RWTH Aachen University, Germany, a four level supply chain model has been designed to investigate the interdependencies between product quality and different demand cases. In this field the FIR is cooperating with the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University, Germany. For the carried out simulation, VENSIM is applied. As shown in figure 1 the model consists of a supplier, a wholesaler, a distributor and a customer. Quality models are each implemented at the wholesaler and the distributor.

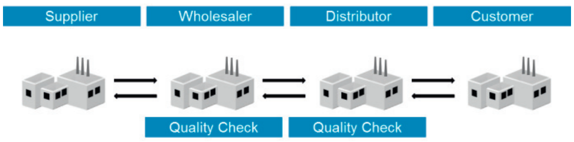

Fig. 1. Four-level Supply Chain

Customer demand is simulated by a data generator which can induce different demand scenarios, i.e. static, sporadic, seasonal, increasing and decreasing functions. For first results the initial order size is set to 40 parts per time unit. After 30 time units the order size is increased to 80 parts per time unit. Table 1 displays the initial setup for the simulation and the different variables.

Table. 1. Initial Setup of the Simulation

General Data	Unit	Value
Duration of the Simulation	Time Units	220
Wholesaler / Distributor		
Minimum Stock Level	Parts	40
Delivery Time	Time Units	2
Initial Inventory	Parts	0
Production Rate	Parts / Time Unit	600
Quality Model		
Average Sample Number	Parts	20
Error Rate	Percent	0
Error Detection Rate	Percent	90
Critical Errors	Percent	10
Level of Acceptability	Percent	10
Customer		
Demand	Parts / Time Unit	40

Depending on the initial setup, i.e. initial stocks, minimum inventory or delivery time, the distributor is sending orders to the wholesaler. Thus, the wholesaler receiving the orders with a delay of 1 time unit is pushing goods along the supply chain to the distributor. In case the wholesaler or distributor is not capable of supplying parts to the next stage of the supply chain, data is recorded in a virtual backlog. Incoming goods for the wholesaler and the distributor run through a quality model. The developed quality model allows different settings regarding error rate, random tests and the distinction between critical and uncritical defects. The quality model works by taking a batch out of the order and checking the defect parts against an acceptance limit. Only one batch per time can be controlled, unchecked parts are put into a queue. Checked parts will be delivered to the next stage of the supply chain. For first results two different scenarios have been investigated. Table 2 represents the different scenarios discussed in this paper.

	Minimum Inventory (parts)	Error Rate (in percent)
Scenario 1	40/1000	0
Scenario 2	40/1000	50

Table. 2. Experimental Design for the Simulation

To validate the supply chain model, error rate was set to 0%. Meaning every part is running through the quality model. In a second step the quality model has been integrated to analyse the interrelationships between product quality and demand. Therefore, the error rate was set to50%.

The data evaluation was carried out by recording the backlog for the different cases. Furthermore, a Design of Experiment approach was conducted, analysing the main effects of the outcomes.