1 Introduction

Logistics – and the physical distribution of goods to consignees as a special interest of Operations Management - have experienced numerous innovations in the past. Many of these innovations have been driven by the so-called 'customer orientation' with its focus on tailored servicing of customers' needs. For this purpose computerized DPS have been developed since the sixties. These DPS use scheduling and routing algorithms (Pachnicke, 2007) to meet customer requirements within their objective of optimising the cost of distribution (or inbound) logistics. Even now there are many research projects and publications on further optimising such algorithms and the cost of transportation. For this research the focus is on studies that deal with Vehicle Routing Problems with Stochastic Demands (VRPSD) which are usually modelled as Stochastic Programs with Resource (SPR). Many of them deal with different meta-heuristics, Simulated Annealing (SA), Threshold Accepting (TA) and Tabu Search (TS) for solutions. (Teng et al., 2003) Whilst many studies focus on the reduction of computational time as measure of the efficiency of the solution process, others deal with the optimisation of vehicle routing and the cost connected herewith. (Fleischmann, 2008, Roehner, 1996, Weisbrodt and Kessel, 2001)

UMTO incorporate a high customer orientation and focus on the needs of their clients. They manufacture goods that meet the specialised and individual requirements of a single client that may never suit any other clients. Consequently, their corporate strategy reflects the highest possible customer orientation. (Tempelmeier, 2003) This orientation may, in some cases, be spread through their entire organisation and consequently along their entire supply and value chain. Their Supply Chain Management (SCM) includes distribution logistics that demonstrate some of the highest operational orientation on customer demands. These customer demands are often directly connected to the nature of goods loaded for transportation in distribution logistics. Transportation from the manufacturing site of a UMTO to its clients is often a niche in transportation management as it may require special equipment and handling operations. In many cases the transportation of UMTO products and its planning dominate the

production planning. This is a circumstance that makes the operations management of a UMTO so challenging and interesting.

Delivery cost for a UMTO as for any other manufacturer or retail firm is an important part of a firm's costing. (Roehner, 1996) The modes of transportation used are driven by economic and operational requirements. (Pfohl, 2004a) Additionally, they often underlie 'customer demands' that may have a variety of reasons. Whatever reasons these may be, the policy of the right product, at the right place, at the right time and in the right quality often dominates the economic aspects in today's distribution logistics. (Shapiro, 2006)

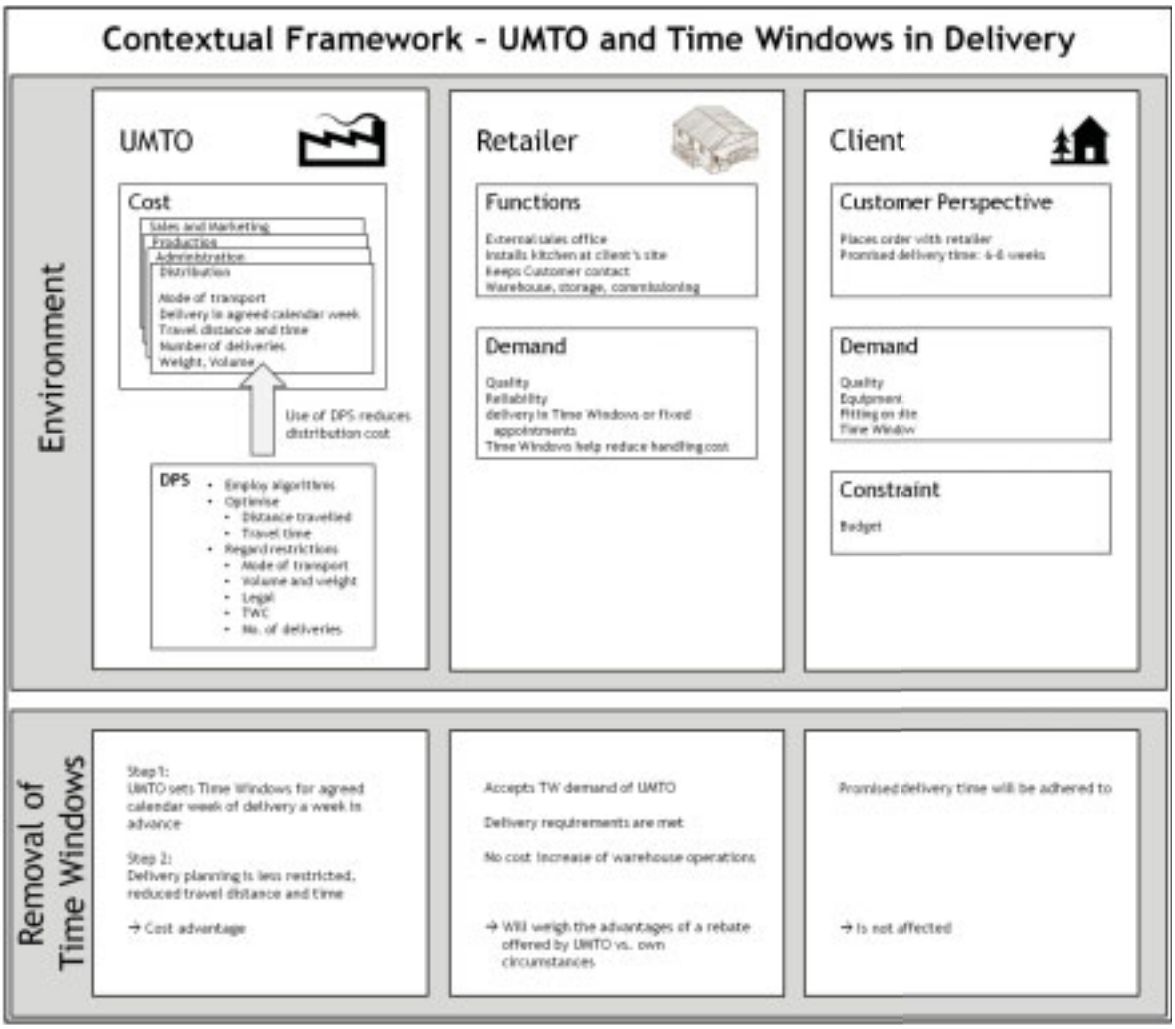

Figure 1: Contextual Framework - UMTO and Time Windows in Delivery

Alternatives to meet the customer orientation by adhering to the constraints of the right product, at the right place, at the right time and in the right quality create different cost in distribution logistics that will be looked at in this thesis. Particularly, it is the question of the right time of delivery that this work will examine by researching the cost of delivery and here, in particular, the effects that time windows for delivery set by the consignees have for UMTO. By doing this, practical established definitions of cost will be used and a focus on the solution process through the relaxation of constraints will be undertaken through the simulation of the *X – Y* model referring to Poe et al. (1994). Once these costs of TWC have been identified, the question arises, whether these costs can be reduced without compromising the service quality perceived by the customer.

UMTO with real delivery data from numerous GKFI manufacturers will be used to generate an initial cost base. The re-routing of deliveries with reduced TWC will form an optimal cost from the manufacturer's perspective. In the process of doing so, the customers' demands of the right product, at the right place, at the right time and in the right quality are still being met.

This thesis will demonstrate for the UMTO industry that the cost arising from TWC may be up to 50% of the entire cost of distribution. This high percentage cost may become a driver for the discussion how to shift the TWC demand from the customer to the manufacturer. The incentive for this discussion is the reduction of TWC in favor of UMTO against cost advantages for the consignees of deliveries. Through such a demand shifting, this thesis will show that resulting from a very competitive market, both, the clients and the manufacturers, can have a mutually beneficial operational and economic basis for such a change. This is the major contribution of this thesis to research and practice.

1.1 Research Overview

In order to understand the complex interactions in a UMTO environment, this section of the introduction will deal with general UMTO problems and describe them using the example of the GKFI. It will show that the market and all its stakeholders influence the value chain of UMTO strongly and extensively. This

will be made especially clear through the competitive structures of this market which will emphasise the importance of distribution costs even more. The following detailed analysis is based upon economic parameters of this industry and the supply chain in the GKFI. This has partly a historical background, evident through the chain of evolutionary business development from after World War 2 until after the unification of Germany. Out of this illustration from the past emerges the picture of necessary changes for the future. This thesis wishes to make its own contribution towards innovative solutions for this industry. This includes in particular the issues within the settings of a production industry which has grown completely out of formerly family-owned businesses in the post-war era. It evolved into industrial enterprises with clients, complex distribution and transportation, new systems of delivery planning and associated costs. These issues will be dealt with in detail later to establish a comprehensive basis for the analysis.

The GKFI were chosen bearing in mind that they demonstrate all the classical characteristics of a UMTO. In addition, this industry is profoundly interested in new solutions regarding delivery cost. In the recent past, it has suffered from a massive domestic sales and profit decline revealing how important – if not essential for survival - the role that delivery costs play measured against turnover and overall profitability. The literature review investigates if, and in which form respectively, research has been concerned with the specifics of UMTO and their delivery costs. Within this context, general planning systems and cost optimisation for delivery of many products are also analysed. After all, this analysis also concentrates on the general DPS characteristics and developments as well as on the meaning of delivery costs in logistics and SCM.

Collection of primary data created the basis for an experiment to ascertain potential DPS effects in a meta-heuristic simulation procedure. This established the core for the actual hypothesis of this thesis, namely that cost reductions from omitting TWC may enable UMTO manufacturers to motivate their clients to accept these changes. Even though this experiment was carried out with the aid of several hypothetical assumptions and purely theoretical constraints, it still showed that the independent variables had in part an extraordinary effect on

the resulting delivery cost. Following this, the results were examined using traditional analysis methods in order to provide evidence of the significance of the independent variables on delivery costs.

Moreover, this research is concerned with transferring information of achieved results to the chosen industry on the basis of supposition. In doing so, the author tried to anticipate the achieved results from this experiment in form of an application model. In this thesis, the model as the research process and the actual cost function with its underlying cost parameters has a clear interdependency. The appendix of this work presents additional analyses of environmental effects to demonstrate that operational changes do have environmental implications. In the past, these environmental and economic interactions were often not directly associated with one another. If, however, one takes into consideration the global framework conditions which emerged at the end of the year 2008, then both the approaches to economy and ecology in SCM and especially in logistics move closer together. Here, one must ask why that is so and how many other global developments will affect the cost of distribution for UMTO in the future. In order to explore this question further, the last section of this thesis's appendix closes with an investigation into the effects which analyses and conclusions may have using the UMTO experimental example. That these effects may also have environmental consequences we have known at least since the existence of global trade with national emission allowances, different charges for starting and loading rights for aircraft, taxation for private and company vehicles in accordance with CO_2 emissions and much more on macro as well as on micro-economic basis. (See Chapter 7 Supporting Environmental Considerations)

The following figure expands on the structural research overview of this thesis. As can be seen, this thesis is grouped into five main sections. The practical background for this thesis is added by the theoretical background and supplies information on the GKFI as a typical UMTO. The research question links directly with the theoretical background and is supported by the literature research that identifies the gaps, which this work attempts to close. The methodological framework of this thesis is also supported by the preceding literature review and

identifies another gap in knowledge through the structural and methodological application of simulation systems in logistics.

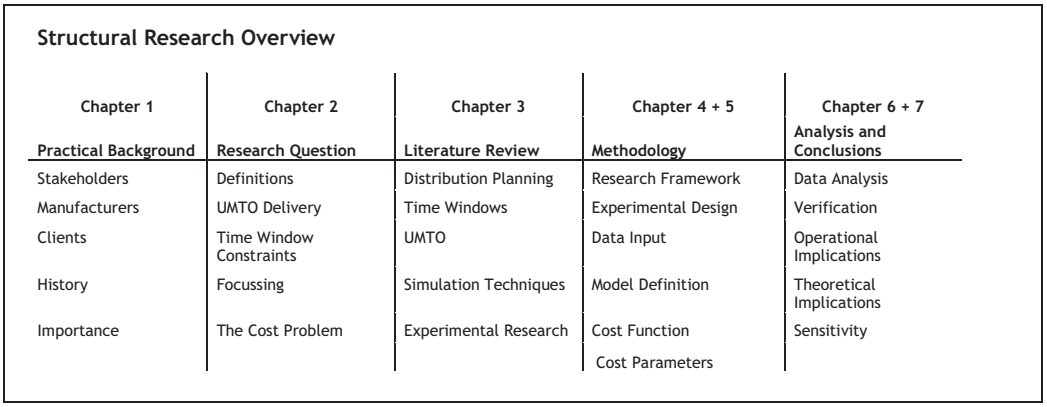

Figure 2: Structural Research Overview

One of the core elements of this research is the definition of the cost function and its application in the simulation system. Here, this application supports the model definition. The analysis and the conclusions are strongly supported by numerous verification and validation processes to support the reliability of the experimental design of this work.

1.2 Theoretical Background

This section of the introduction chapter will provide the theoretical background on three major subjects related to this thesis. Further details arising here will be also discussed and described in Chapter 3 of this thesis:

a. distribution planning systems and their use in theoretical analysis;
b. unique-make-to-order manufacturing and its requirements from distribution planning and
c. the importance of distribution cost.

Research in the field of vehicle routing started as early as 1959 with the truck dispatching problem posed by Dantzig and Ramser (1959a). The result of their

findings said: *"No practical applications of the method have been made as yet."* (p.90) Since the publication of their work in 1959, further research on the VRP has increased dramatically. Golden et al., (2008, p. VI) report that, in 2008, *"…a Google-Scholar search of the words vehicle routing problem yields more than 21,700 entries."* This shows that in the past 50 years this problem has continuously gained interest for researchers all over the world. Further research expanded on the vehicle routing problem with time windows (VRPTW). Here, Toth and Vigo, (1987) summarized their findings as: *"a collection of exactly K simple circuits with minimum cost, and such that:*

a. *each circuit visits the depot vertex;*
b. *each customer vertex is visited by exactly one circuit;*
c. *the sum of the demands of the vertices visited by a circuit does not exceed the vehicle capacity, C; and*
d. *for each customer, i; the service starts within the time window* $[a_1, b_1]$ *and the vehicle stops* s_1 *time instants."(* p.2)

From those findings and based on the above definition, a large variety of heuristic algorithms for the VRPTW have been developed over the years. (Gendreau et al., 2007 pp. 143-144) They state and summarize them as follows:

a. *ant colony optimization,*
b. *genetic algorithms,*
c. *greedy randomized adaptive search procedure,*
d. *simulated annealing,*
e. *tabu search,*
f. *variable neighbourhood search and*
g. *others*

All of the above techniques represent either a single or a combined metaheuristic methodology to 'further optimise' the VRPTW for capacitated vehicles starting from a central depot, serving a number of clients with soft or hard time windows and returning to the central depot with or without backhauls.