Supporting Hypermarket Chain Leadership with Data Management Tools in Competition Strategy Implementation

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Abstract

This dissertation describes the decision support methods and operating models used in the development process of the S Group’s Prisma hypermarket chain in Finland in 1990-94. Fierce competition forced management to look for new business ideas, tools and methods that would provide a clear competitive advantage for the rapidly growing chain. In order to find new perspectives, it was decided to use statistical approaches and various Decision Support System options. For the research and analysis, a large database was compiled, including data on purchasing behaviour, Key Performance Indicators (KPIs), customer and product records. The main focus of the development was to identify and profile customers, how they behave and to find new innovative ways to meet their expectations.

In addition to Descriptive Analysis and Multivariate Statistical Methods, the development project also generated new ways of looking at chain performance, both from the perspective of a single unit and the chain as a whole. An Ordinal Principal Component Analysis method was developed for intra-chain benchmarking and used for multicriteria ranking between units (Article 1), a Data Envelopment Analysis method was used to assess efficiency, extended with the concept of Value Efficiency Analysis (Article 2), and a Decision Support System was developed for strategy work to provide perspectives for scenario building and monitoring (Article 3). The immediate contribution of DSS modelling to decision making came from its ability to provide Decision Makers with sensible, better solution options to support their decision making.

The final impact of decisions could be assessed over a longer period of time, which in the case of the Prisma development project results meant several comparable financial years and eventually decades. Finland suffered exceptionally badly from the financial crisis and the global economic downturn in 2008-2009. The Prisma chain has survived the periods and crises described above without any loss-making years, and the whole chain has grown from 16 units in 1992 to 68 units in 2020.

Keywords  Customer Analysis, Decision Support System, Multiple Objective Linear Programming, Performance Improvement, Retail, Hypermarket, Multivariate Analysis, Shopping Basket Analysis
Supporting Hypermarket Chain Leadership
with Data Management Tools in
Competition Strategy Implementation
Preface

I have received guidance and support from many people during my doctoral studies. I am very grateful to my supervisor, Professor Emeritus Pekka Korhonen, for the opportunity to work with him. He is also my co-author and an old friend who encouraged me to start writing this dissertation after many years in the business world. I would also like to thank my supervisor, Professor Markku Kuula, for his encouraging and constructive interest in my research and for his valuable comments on the manuscript. I would like to thank Professor Emeritus Jyrki Wallenius for his significant contribution during the painful journey of completing the dissertation.

I would also like to express my deep gratitude to Dr Margareta Soismaa, who is also one of the authors of my second article, for her long-term friendship, help and support. I would also like to express my enormous thanks to Dr Merja Halme, who, back in the 1990s, gave me the opportunity to talk about the implementation of a competition strategy in a hypermarket as a case study in her lecture series Marketing Models. I would also like to thank the research team of the Department of Information and Service Management at Aalto University for fruitful discussions and support.

During many years I have had the privilege of working with many excellent colleagues, whom I would like to take this opportunity to thank from the bottom of my heart. I would like to thank my long-time collaborator and friend Kari Huju, who worked as an Operational Expert and time to time as a Deputy Chain Manager during the production of the content of my articles. Thanks are also due to Harri Mönkkönen, who served as the Prisma Chain Manager during this development process, for the inspiring discussions and reference suggestions I have used in the summary paper.

Thanks are also due to Tapio Kankaanpää, who was the manager of Pietarsaari Prisma during the study, and to Juha Salmi, who worked in the Prisma chain and later as the line manager of the S-market chain of the Arina cooperative store. Through them, I have gained significant practical experience of hypermarket operations at both national and regional level.

I would also like to express my great thanks to my consultant colleagues Martti Makkonen and Hannu Swan, with whom I have had the privilege of working on development projects for large companies. The experience gained from these is also reflected in this work.
I would also like to thank the NumPlan staff, especially Pia Sundström and Jelena Jalonen, who have both been invaluable in providing support, help and practical maintenance during all research years. Extensive Customer Surveys required large volunteer work periods, for which I would like to thank my friends Reija and Lasse Niemelä in particular.

Special thanks go to my sister Dr Maija, who has encouraged and helped me during the thesis and my brother Antti, who has supported me on this rocky road, and my other siblings Esa, Aino, Esko for their encouraging support.

Finally, I would like to thank my family. My children Lauri, Paavo and Meeri have been interested in my studies and have supported me and encouraged me to continue, even if sometimes my enthusiasm has been lacking. I would like to dedicate this thesis to my wife Riitta, whose love and constant encouragement throughout the years of the thesis have made this great spiritual project successful.

Nummela, February 2022

Aapo Siljamäki
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List of Publications

This doctoral dissertation consists of a summary and of the following publications which are referred to in the text by their numerals


Author’s Contribution

Publication 1: "Ordinal Principal Component Analysis: Theory and an Application"

Siljamäki participated in the development of the idea and the research and analyses and contributed to the writing of the article. Siljamäki also carried out the necessary test and production data required for the method.

Publication 2: “On the Use of Value Efficiency Analysis and Further Developments”

Siljamäki participated in the development of the idea and the research and analyses and contributed to the writing of the article. Siljamäki also carried out the necessary test and production data required for the method.

Publication 3: “A Decision Support Approach to achieve competitive advantage for a hypermarket chain”

Siljamäki is the sole author.
1. Introduction

The common denominator of this dissertation is a Finnish Hypermarket chain, whose development and strategy implementation the author of this thesis has participated in the years 90-94, when the large-scale and systematic development of the chain began. The author acted as a methodological expert and external consultant for the chain throughout the project, being responsible for generation and use of scientific methods. He was also responsible for solutions, software and analysis based on data sources, data collection and database architecture.

Developing a hypermarket-sized chain requires a clear and targeted competitive strategy and a good set of metrics for strategy implementation and monitoring. Leading the chain towards strategic goals requires good methods and ways of communicating to chain staff what is desired and required to be done. Providing decision support tools and analyses has been an essential part of this whole development process. It has included development of various analytical packages, field work and modelling with different outputs and tools. Almost three decades have passed since the initial stages of the chain's development, and now we can see how the chain has continued to grow and developed to become the market leader in the Finnish grocery market. (Finnish Grocery Trade 2020).

1.1 Background

Hypermarkets entered to the Finnish grocery market in the early 1990s. New business ideas and ways of working had to be developed for hypermarkets. The S Group’s Prisma chain was a pioneer in this development in Finland and right from the start created a significant market position in the competition between chains with its new business ideas. (Finnish Grocery Trade 2005-2006)

The Finnish grocery trade underwent a major structural change between 1995 and 2013. Finland joined the European Union in 1995 and the economy became increasingly integrated with those of the EU countries. Finland joined the common euro currency of the EMU countries in 2002. In 2003, the Finnish grocery trade was still concentrated in urban areas, where 43% of grocery stores were located, 53% of groceries were sold and 54% of the population lived. (Finnish Grocery Trade 2020).

In the midst of the retail turmoil, they wanted to develop a new chain of efficient hypermarket-sized stores, with units with sales space ranging in size between 9000-10,000 square metres. The units will be located on the outskirts
of the growth centre, with large parking areas for customers. This has generated the term car market, which is used in this paper in parallel with the term hypermarket.

While car market chains were new to the retail sector in the early 1990s, the early years of Prisma’s growth required a self-driven search for new ways of doing business, the creation of business ideas with competitive advantages and the building of a sustainable strategy for a scaling chain. Measuring the success of chosen competition strategy became crucial. It was necessary to be able to verify the status quo using various indicators, to be able to take the necessary corrective action and to see the impact of the solutions adopted.

All this required a significant number of systems and methodological work, where the author has been a methodological architect applying and developing various statistical analysis methods and decision support systems to support strategy work.

Decision support in enterprise development is seen in this study as an approach where management and organisational decision making is supported comprehensively by various statistical and data processing methods and by using Decision Support Systems (DSS) to understand strategically important structures and to make wiser and better decisions. We see the decision support approach as a process, where methods and models are combined in constantly changing situations and the results of the process are only visible after a longer period of time.

A Decision Support System is an information system that supports business or organisational decision making. DSSs serve the management, operational and planning levels of an organisation (usually middle and senior management) and help people make better decisions about problems that can be fast-changing and not easily defined in advance, i.e. unstructured and semi-structured decision problems. DSS can be either fully computer-based or human-powered, or a combination of both. (Bohanec, M., 2001)

The field of Decision Support (DS) and Decision Support Systems has expanded into a discipline that focuses on supporting and improving managerial decision making. In modern professional practice, DSSs include personal Decision Support Systems, Management Information Systems (MIS), Online Analytical Processing Systems (OLAP), Data Warehousing (DW) and Business Intelligence (BI). (Kimball, R. and Ross, M., 2013)

In this summary, DS refers to the planning, development, analysis and modelling service package for the chain’s management, the aim of which is to make the Prisma chain the market leader in the Finnish grocery market. The Decision Support Systems and analysis chains presented in the summary are, as case studies, good examples of typical practical decision support work. There is a desire to see the big picture from a "helicopter perspective", where the different subsets are built up over time and functionally and how they are linked to each other.
1.2 S Group and Prisma Hypermarket chain

S Group is a customer-owned Finnish retail and service network with more than 1,800 outlets in Finland (2019). The S Group includes cooperative stores and SOK and its subsidiaries, which operate in the travel and hospitality sector in countries such as Estonia and Russia. The S Group cooperatives are companies that operate according to the principles of cooperatives. Their owners are also their customers, i.e. members of the cooperatives.

The S Group operates in supermarkets, hypermarkets, department stores, speciality stores, petrol stations, fuel sales and travel and catering. The market trade consists of five market chains of different sizes and with different service offerings, of which Prisma is the largest car chain. (S Group in brief, 2021)

SOK Group’s market trading business includes operations in Estonia and Russia. In Estonia, there are six Prisma stores in Tallinn, two units in Tartu and one in Narva. (S Group and Responsibility, 2020)

The Prisma chain in its current form was born in 1988, when the S Group started to group its stores under national chains. SOK considered Prisma to be a successful brand, so it was introduced in all the hypermarkets of the S Group. The product ranges and marketing of the stores were harmonised. At the end of 1995, there were 28 Prisma stores in Finland. In November 2019, the Prisma chain had 68 stores and an online store. Prisma also has stores in Estonia and Russia. The sales area of Prisma stores varies between 4 000 m² and 14 000 m².

Although each unit in the Prisma chain operates independently, certain functions such as assortment planning, product placement, logistics and strategic decision-making for the whole chain are planned and managed centrally. Product and customer databases are managed both centrally and locally.

In the 1990s, the Prisma Chain Management Board (PCM) consisted of representatives of centralized chain management and Prisma managers. The PCM made all major operational financial decisions, so it had the final say in the development process and was responsible for the existence of the projects. From the point of view of decision support, the PCM's role was to act as the final decision-maker. All major projects involving the Prisma units had to be justified and committed to at the annual meeting of the unit managers.

The Chain Manager (CM) and the Chain Operations Expert (OE), together with the External Methodology Expert (ME), were responsible for the development and implementation of the overall multi-criteria decision support systems. All major operational projects had to be justified to the PCM, which in the 1990s consisted of the CM and five Prisma managers, and the implementation of these projects had to be approved separately.

1.3 Parties and roles

The author of this thesis, who acted as a methodological expert and external consultant for the Prisma chain throughout the project, has been responsible for the knowledge and use of scientific methods. He was also responsible for
solutions, software and analysis based on data sources, data collection and database architecture.

The role of decision support is to help the decision-maker make better decisions by finding wise solutions. This requires collaboration, where the methodological expert(s) and the company’s operational and managerial staff work together to find solutions that meet the objectives.

The role of the Operational Expert (OE) in the chain development working group was demanding. The OE is involved in the practical design, implementation, validation, verification and reporting of the results of the analyses. He had to act as a link between theory and practice. The implementation phase is usually the most challenging phase of the work, when the gap between the traditional and the new vision are faced and a common understanding of the future approach is sought. The role of the operational expert has been to provide all the necessary input from within the organisation and to be largely responsible for implementation at field level.

Decision-maker(s) and decision-making in the development work has been in the hands of the Chain Manager (CM) and the OE. This has enabled a rapid cycle from one decision to the next. Decisions within the projects have been taken within the given framework conditions, conditions defined by the PCM. The PCM has consisted of five (5) chain managers and the CM, with the OE as rapporteur where necessary.

2. Implementing the competition strategy using a Decision Support Approach

2.1 The customer at the heart of everything

Strategic management is a continuous process, where you need to be able to measure both the quality of the strategic plan itself and its implementation. In its simplest form, strategy - a process - is described as planning and implementation. We plan, analyse and evaluate the results, and when we are satisfied with the results gained, we move on to the implementation phase. In theory, this works well, but in practice we need to consider at least the link between planning and implementation and the ways in which the people involved in the process shape actions and perceptions.
The customer is in the heart of Prisma chain development. All of the strategic planning were aimed at serving the customer, listening to the customer and creating added value for the customer.

**Figure 1. Competition strategy of the Prisma chain**

The key objective of the Prisma chain's competition strategy was to produce a superior hypermarket chain for the Finnish grocery market. The strategy was defined by customer focus, i.e. easy shopping, reliable and consistently low prices, and profitable and efficient operations.

The competition strategy focused on:

- customer efficiency, which includes customer expectations and experiences, and measuring success with customer satisfaction,

- unit efficiency, through customer and assortment efficiency, the right placement and volume of goods available in each market, and good customer service, which become apparent in sales, inventory turnover, margin and profit,

- internal efficiency of the whole chain, generated by following best practices. To achieve this goal, efficient units had to be created that worked well as part of a chain. To be effective, the whole chain must have a common set of strategic rules for managing, monitoring, and improving. This requires good metrics that measure the units and the chain in the right and fair way and in a way that supports the strategic objectives, so that all units are treated in the same way.

### 2.2 The Research Database as a collection of information

The competition strategy process generated a huge amount of knowledge and processed information. This information was stored in a research database. You never knew what information might be used at some point, that's why it was all kept. The research base was designed to be dynamically shaped over
time. It was better to collect too much data than too little. This provided good 
optunities for ad hoc working, which was almost the main modus operandi 
throughout the project. This was due to the fact that, when conducting research, 
the need for further investigation was often identified, generating the need to 
act in the here and now.

The data was kept in a relational database, with ME as the database architect, 
developer and user. The structure and use of this were both off the shelf and 
ad hoc, extracting and combining things using SQL-type queries and self-
developed software. We had the possibility to use the data and results from the 
different analyses and to make comparisons between time periods like BigData-
type data mining. (Dean, J.,2014)

**Hard values and KPI data**

In the Prisma chain, the chain unit has its own cash register systems and part 
of the administration systems. Financial management is centralised on the 
regional cooperatives’ own servers. These management systems make available 
the so-called hard values and Key Performance Indicators (KPIs) for operations 
and performance. For the study population, both unit-specific data and chain-
wide KPI information and normal performance reporting were available.

In order to understand more about the functioning of the unit, the role of cash 
data had also to be considered. The data consisted of all the transactions that 
took place within the cash system of the unit. Receipts were recorded in the 
system with detailed information. From a chain development perspective, it was 
found that KPI data alone did not identify the flow of transactions within the 
units and that a closer examination of the cash register data was necessary. This 
created the need for shopping basket analyses.

**Product and customer information**

The research database included those parts of the regional cooperative’s in-
formation systems from product and customer data that could be used for data 
mixing and merging. The product data used included product grouping 
information, pricing and characteristics information. For customer data, 
information was used to look at family structure, mobility, customer card usage, 
etc.

There were about 30 thousand products and about 5000 customer records.

**Shopping basket data from cash management systems**

Shopping basket data were collected for 7 months, primarily from one pilot 
unit, with individual samples from a few other units. The Pietarsaari unit was 
chosen as the pilot unit, as the preconditions for data collection were favourable 
and the unit was a suitable target for the chain’s strategy.

Shopping basket data and shopping basket analysis are discussed in more 
detail in the third article "A Decision Support Approach to achieve competitive 
advantage for a hypermarket chain". It explains the steps of the analysis and 
how the receipt data was transformed into a useful input for further analysis by 
combining the receipt data with product and KPI data.
Business idea meter data through customer listening

Measuring strategy is an art in itself. It requires the use of imagination combined with solid professional skills. (Ylisirniö, P., 2011) In the Prisma chain, the Business Idea Meters (BIM) became the basis for measurement. We wanted to measure with customers whether we were performing in line with expectations and at what level. The number of business idea indicator was stabilised at 33.

Business idea metrics played a major role in the survey population. Their significant value is as a measure itself and also as a classifying factor. A huge number of different perspectives accumulated in the database, which could be used in ad hoc surveys to generate new information.

The business idea meter data was collected through customer listening. The customer survey was carried out in all chain units in years 90-94. The survey collected a variety of customer expectations and experiences of the Prisma unit and Prisma as a shopping place, based on different perceptions. A huge database was created from these surveys, containing both quantitative and qualitative data for further mining.

2.3 Customer efficiency as a focus for measuring strategy

2.3.1 Customer-oriented basket grouping

In the early 90s, the Prisma chain was the first hypermarket chain in Finland to launch shopping basket analysis. Being a pioneer is always hard work and often a journey of trial and error. Shopping basket data was collected for 7 months, primarily from one pilot unit and individual samples from a few other units.

Each shopping visit generates a checkout transaction, which is summarised in a receipt with information. It records the time of the transaction, the checkout number, the transactions in the order of their occurrence with product numbers, prices and quantities. Customer data is recorded on the basis of the payment method, in the case of customer card transactions, debit card transactions or cash transactions. All receipt data are recorded in the cash register system on the central computer of the Prisma unit.

Daily and weekly shopping basket reports were produced for decision-makers, allowing them to present the basket structures in different ways. Correlation analysis provided information on the interdependencies between product groups. Using Principal Component Analysis (Rencher, A., 1998), clear shopping basket structures were found on different days of the week, there were clear grocery shopping baskets, clear household shopping baskets, etc. There were shopping baskets arising from minor purchases and thus indicative of errands where people just popped in to buy e.g. cigarettes and newspapers. This monitoring, the discussions and the analysis of the reports in the groups, taught the staff of the units and the product group managers new things about customer behavior. All this provided decision support directly to the operational level.
Customer-oriented basket grouping produced congruent customer groups, which could then be targeted with clear measures. Instead of several thousand anonymous customers, attention can be focused on congruent groups. If/when these groups of clients still remain similar from day to day and week to week, one can also be confident that the measures taken are the right ones.

Findings from the basket analyses

The most striking finding from the outset was that a significant proportion of all baskets were of low average purchase. The expected and desired target group for the Prisma was "a family with children of growing age who drive and do their basic shopping 1-2 times a week at the Prisma". The result was inconsistent with the assumptions and objectives. Further analyses revealed that the average purchase was significantly influenced by external factors. The unit was located in the centre of the city, close to schools and residential buildings, where it was easy and quick to get to. By monitoring shopping times and basket contents, it was possible to see how there were clear "spikes" in the results for school recesses.

The extended shopping basket data was used to discover many aspects of the shopping experience - how customers act at the time of purchase, when the purchase is made, which product groups are used, how product groups are related to each other, how to use the extended shopping basket information to find families with children or families that bake, clean, repair a car, etc.

However, the shopping basket analyses showed that the objectives of the competition strategy need a broader set of data to support decision-making. More should be known about the customer. The customer is an asset that requires extensive data collection and further analysis to understand.

Immediate actions after shopping basket analyses

The results were used as a basis for sizing the number of cash registers and the way they operate. More detailed information was now available on daily, weekly and special situation cashier workloads. It was possible to proactively size staffing and perhaps the most significant change was the inclusion of the 'express checkout'. All potential customers with a small shopping basket were directed to this cashier.

From shopping basket analyses to customer satisfaction surveys

The shopping basket information significantly helped decision-makers to understand the structure of their customer base. However, research continued to point towards the need to know more about customers and to be more selective in the information that is actually derived from shopping baskets. There was a need to clarify, for example, the role of small customers, as highlighted above. Are they really only buying part of their family's products from a large supermarket, or are they customers who usually shop at a car market, but only this time have bought a small basket.

To address these issues, customer listening surveys were launched in connection with shopping basket analyses. All Prisma units participated in this survey every year. In one year, shopping basket information was collected from
six units at the same time. Customers were asked to enter their shopping receipt number in their questionnaire, which served as a lottery ticket number for a prize draw for a valuable shopping card for Prisma.

From the joint data, it was possible to establish that most of the small shoppers were regular Prisma customers who, for one reason or another, only bought a small amount at Prisma this time. Another important finding was that if customers are grouped and studied on the basis of shopping basket information alone, we are only looking at the past. What the customer thinks, plans, decides in terms of shopping is not being looked at.

### 2.3.2 Customer surveys to listen to customers

Customer listening became a key element of the competition strategy. It was used to establish a dialogue between customers and Prisma’s operators. The purpose of the customer survey was to gather information on customers’ perceptions of the Prisma, the Prisma unit, the way of doing business, the quality of products and services and, in a free-format style, other possible factors related to this.

The customer survey was carried out once a year for five years. This included listening to all units at the same time and in the same way. In each unit, the management was engaged in the survey round. The most concrete evidence of this was the distribution of the questionnaire to the clients by the management of the unit and the initial guidance on the structure of the response. In some years, they distributed a coffee packet to clients as a thank you for responding. This rewarding in advance was seen as a good gesture. Free comments revealed, among other things, that the fact that they had been rewarded in advance for their responses was a factor in the response rate. The questionnaire was 5-7 pages long and required a time commitment from the customer, which was taken into account in this way. However, customers were willing to participate, with response rates ranging from 60-90% in all units.

The Prisma chain invested in customer listening. The annual survey was carried out by an external consultancy firm, with ME in charge of the whole operation. Prisms were located throughout Finland and all operations were carried out without the current extensive online net services. The forms were printed in a printing house, distributed to customers in the car markets, sent by letter post to a storage company, where the data was changed to digital format and made available to the consultants for analysis. This huge process took 1-2 months. In some years, the survey was further extended by collecting car registration numbers from the front of the unit’s competitors at the time the survey was conducted, mailing a Prisma form to the car owners based on the number, and obtaining “a comparative basis” to support the study. And all this to get the maximum amount of information to tell us why customers do or do not visit Prisma and how we can best serve our customers’ expectations.
2.3.3 Business idea indicators

The key elements of the customer survey were business idea indicators. These indicators were developed in order to determine the customer perception of Prisma, its services, products and way of doing business and to create concrete tools for evaluating its efficiency. In implementing the competition strategy, it was essential to see the impact of the actions already taken and to create new ways of making a difference. Hard values and KPI metrics help to identify the financial situation and position the chain in a nationwide grocery market, but development requires forward-looking information. For this task, Prisma’s business ideas were used to create meters for the development work. The business ideas were collected and refined from within the S Group to serve the needs and objectives of the Prisma hypermarket. In total, 33 indicators were established as business idea indicators. The starting point for each individual business idea meter was to provide a picture of the customer expectations and experiences when visiting a Prisma.

An example could be the business idea: "it’s easy to move around in the corridors". This feature/issue is familiar to everyone today, but at the time of development, storefronts were cramped, difficult to navigate and especially difficult for large families. We wanted to know how the customer perceives the instore experience: is this relevant and, if so, does Prisma meet this challenge?

Expectations, Experiences and Success

Each business idea was measured in terms of both expectations and experience. This was done in a questionnaire with a pair of questions for expectations and a pair of questions for experiences. (Bergman, B. and Klefsjö, B., 1994)

A series of questions corresponding to expectations was initialised with a question: How do you choose which car market to go shopping in? This was specifically intended to seek answers to the question of the relevance of the Business idea meters in the minds of customers. For example, is the choice based on "... having a good range of goods" or "... being easy to get around"?

The scale used was 1...7, with 7 being "absolutely important", 1 being "not very important" and in the middle "somewhat important". The choice of scale was based on pilot studies and we felt that a well known Likert scale was the most appropriate. (Wuensch, Karl L., 2005)

In a similar way, experiences were mapped by asking the initial questions: 'How do the things listed above fit with this business? The scaling values were defined as, 7 is "handled commendably", 1 is "definitely needs correction" and in the middle "is just about right". This scaling was aimed as "boosters" for the work list of the chains' product group managers.

The common measure of expectations and experiences is success, which was produced on the principle of success being 100 when experiences and expectations are equal, otherwise exceeding expectations, success status is above 100, underperformance below 100.
Business idea indicators for customer-oriented groups

Responses were grouped using statistical cluster analysis, with expectations as the grouping criterion. Business ideas were grouped according to five concepts: ease of purchase, service image, availability, reliable price/quality and staff performance. From these, new concepts - variables - were created to measure strategy and efficiency and guide the chain towards its objectives. For this and all other grouping needs we used the Clustering Algorithm developed by Pekka Korhonen (Korhonen, P., 1978), where cluster analysis uses Wilks’ lambda as a criterion, which can also take into account the correlation structure within groups.

The grouping software was developed by ME. The software was written on the Windows platform for Delphi (Buchanan, W., 2003) and MS Visual Studio application developers. The latest versions of grouping software were produced in 2021 in collaboration with Pekka Korhonen.

<table>
<thead>
<tr>
<th>Ease of buying</th>
<th>Reliable price and quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Located so that easy to enter</td>
<td>There are good special offers</td>
</tr>
<tr>
<td>It's quick to do business</td>
<td>There are permanently low prices</td>
</tr>
<tr>
<td>There is good parking</td>
<td>Have high quality products</td>
</tr>
<tr>
<td>Easy to move around the corridors</td>
<td>Easy to buy without a salesperson</td>
</tr>
<tr>
<td>There are fast checkout services</td>
<td>Products are reasonably priced</td>
</tr>
<tr>
<td>No queuing</td>
<td>The quality of the products is reliable and</td>
</tr>
<tr>
<td>Easy to make a shopping trip</td>
<td>assured</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Service image</th>
<th>Staff performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offers good benefits to regular customers</td>
<td>Prices are clearly and correctly displayed</td>
</tr>
<tr>
<td>Play and care facilities for children</td>
<td>The most common phenomenon is spacious,</td>
</tr>
<tr>
<td>Products attractively displayed</td>
<td>comfortable</td>
</tr>
<tr>
<td>Products on display are up-to-date</td>
<td>There are reliable checkout services</td>
</tr>
<tr>
<td>Products are fashionable</td>
<td>There is professional staff</td>
</tr>
<tr>
<td></td>
<td>There is friendly staff</td>
</tr>
<tr>
<td></td>
<td>There is neatly dressed staff</td>
</tr>
<tr>
<td></td>
<td>Its facilities are clean</td>
</tr>
<tr>
<td></td>
<td>The environment is clean and hygienic</td>
</tr>
<tr>
<td></td>
<td>There are no obsolete products on display</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Availability</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>There is a good range of products</td>
<td></td>
</tr>
<tr>
<td>I get all the products I need</td>
<td></td>
</tr>
<tr>
<td>Products are available throughout the opening hours</td>
<td></td>
</tr>
<tr>
<td>The departments are clearly laid out</td>
<td></td>
</tr>
<tr>
<td>Products are well displayed</td>
<td></td>
</tr>
<tr>
<td>It is easy to find the products</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Business idea indicators grouped by expectations

The purpose and aim of the customer consultation was to provide clear messages and worklists for the departments on where to focus their attention in order to achieve the objectives of the competition strategy. All the results were discussed among staff in the departments. For this purpose, ready-to-use worklist reports were available for all measured elements. These were designed so that areas for improvement could be addressed immediately. Main aspects:

- Expectations and experiences in relation to the business idea indicator.
- Highlight the main areas for development and the GAB (experiences - expectations) in each of them
- Expectations in order of importance
- Experiences from worst to best, a ready-made development list
• Success in order of ranking
• Success by product group, a worklist of product group managers

The results were also presented to Prisma’s customers. All the most relevant results were taped on the walls of the entrance to the units for all to see. This created transparency and customer feedback showed that this was appreciated. Whether the results are good or bad, they need to be communicated.

Figure 3 shows an iconic example of the photo galleries on the wall of the Prisma. The results were presented as A4 reports, each providing perspectives on the results described above. The images and reports were also annotated and brief reading instructions for the results were provided.

The aim was to give customers the experience of being cared for and listened to. At the time of the presentation, such a process was identified as a new, refreshing and constructive way of emphasising the customer relationship. In terms of chain development, this achieved a number of different objectives. Customers felt that they were involved in the development, the Prisma staff and its activities became closer to the customer, and at the same time there was ‘pressure’ on those responsible to act in the direction indicated by the strategy, as the reports showed clear areas for improvement.

Products and services
The business idea meters were used to find out customers’ expectations of the car market. The combined effect of expectations and experience was used to
identify how successfully the customer has been served. Together, these provide pressure to act, especially if they reveal unsatisfactory customer service. Addressing this requires concrete action, which can be taken within the unit through more efficient product groups and services.

The quality of the product groups and the services related to them were measured in the context of customer listening surveys. The measurement was based on a scale of 1-7 on the Business Idea Scale plus the options, “We don’t use” and “We buy elsewhere”. These two refinements gave the respondent the option not to rate the product group but to indicate that the product group was considered.

The purpose of the measurement was to produce worksheets for the units’ product group managers, to provide information to the assortment planners on the use of product groups, and especially on unused and resupplied product groups.

Figure 4. Output sheet for the product key managers - Use of product groups

Figure 4 shows an example of an analysis by product group. The target product group is bread. This product group includes several different bread products, i.e. the information applies to all of them together.

For each product group, tables as shown in Figure 4 were produced for the product group managers of the Prisma units. On the basis of these, explanations for buying and not buying were sought in the units. To support the analysis, it was also possible to produce data on product groups and business ideas, as well as customer background information, allowing for a very detailed analysis.

All this work was done in the units. The work was motivating when the author was provided with sufficient information to support his decision making.
General image of the unit and competitors

During the implementation of the competition strategy, the main indicator to be monitored was the overall perception of the entity being evaluated. This was called Customer Satisfaction, a general indicator that describes the overall situation of the unit being measured. At the chain level, this indicator was used to make all units comparable and jointly measurable. The fact that the value of this measure varied between units was explained by other measures obtained during the process.

Customer satisfaction was the first thing sought in the customer satisfaction questionnaire. This explicitly sought a "sense of first impression" from the customer. On a scale of 4 to 10, the respondents were asked to give an overall assessment of the car market as a shopping destination as a whole? The questionnaire also provided the opportunity for the respondents to justify the given rating.

Prisma was very successful in the listening surveys. Response rates were between 60-90% all the time and best of all customers took a lot of time to comment freely. In terms of public perception, significant additional information was gained to help with measurement and action. All arguments were recorded and analysed.

At the same time as the Prisma unit was being assessed, they were also asked to assess competitors in the area and justify their assessment. All of this created a huge database of information for development and field staff. The comments were documented and produced as reports for the different working groups in the Prisma units, where they were extracted and transformed into tasks.

Free comments and images

The free comments were analysed more extensively over the course of one year. This resulted in more than 13,000 free comments, which were coded, classified and structured. This analysis provided a clearer picture of how customers perceived the Prisma chain, what expectations they have of services, products, staff and what they complain about.

The content of the comments and the results of the analyses were presented and shared with the individuals responsible, whereas solutions and clarifications were sought in working groups.

2.4 Efficiency of the assortment to meet customer expectations

Useful information on the use of the product groups was collected through customer listening. In the same context, it was also possible to find explanations of the situation at the time of conducting the survey through the use of indicators and free comments measuring customer perceptions of the Prisma.

Assortment planning was carried out centrally at chain level. The planners had access to product level data on sales, stock, wastage, purchasing, etc. Customer listening provided new tools for assortment work, allowing customers to be viewed in predefined groups, making assortments customer-driven. In car markets, selections could be made in several categories based on the size and
location of the unit, where each group was designed taking into account the size of the unit and the needs of the customer.

Product placements, store design
Customer listening also guided product placement and store design. Through customer feedback, new ways of allocating shelves and departments in the units were found. To a large extent modelling tools are used in companies for this purpose today, but customer feedback always reveals nuances that would otherwise go unnoticed.

For store planning and assortment management, Prisma used the Spaceman system during the planning and maintenance phase. (NielsenIQ, 2021)

2.5 Unit efficiency to meet external requirements

At chain level, good and comprehensive reporting of hard values and KPIs was available. This provided information on the accounting situation of the units. However, for the development of the chain, a number of external factors have to be taken into account, which determine the content of the steering activities. For example, the sales space of a unit must be sized correctly, taking into account local conditions, the potential for structural solutions and, in particular, the objectives of the chain’s competitive strategy.

The relationship between units, sizes, assortments, KPI values and the structure of the whole chain were assessed and analysed using statistical ratio analyses. In this analysis, a matrix of observations was constructed for the whole chain, where the observations were the units and the criteria were different KPIs for the units. The number and quality of these varied, but the aim was to include all the indicators that could be commonly used to measure units.

KPI analysis was used to find correlations between criteria, regression analysis was used to find the interaction of several criteria (independent variables) with a desired criterion (dependent variable) and traditional spreadsheet methods were used to classify, group and rank the data.

Behind all these analyses was the competition strategy to get the units to work together as an efficient hypermarket chain. The units had to be sized and positioned correctly, their internal product mix had to be designed within these parameters, and logistics had to be made to work in line with customer needs.

Unit ranking
Comparing units is a basic function of ranking, where you want to see the units in some preference order. This sorting is easy and simple to do with today's spreadsheet tools. But how to find the "right" and common order for the units when you want to take into account the impact of more than one criterion at the same time. This issue has been addressed in the first article of this study, where units were measured by four different criteria, using an ordinal scale. This analysis was used to explore ways for chain managers to compare units with each other in order to make the units as comparable as possible and the common measure as fair as possible.
This mutual comparison and evaluation is part of the ranking. Prizes are awarded to the best and internal benchmarking adds value to the whole chain. It seeks answers to why one unit is better than another and what should be done to make a less efficient unit more efficient.

2.6 Chain efficiency in line with best practice

2.6.1 Evaluation of the Efficiency by DEA/VEA analyses

One of the cornerstones of the competition strategy is internal efficiency, which refers to how the strategic objectives are achieved within the unit. A separate efficiency study was conducted for the Prisma chain in 1997 to investigate this. (Siljamäki, A. and Korhonen, P., 1997)

The starting point of this study was to determine the efficiency/inefficiency of Prisma units using accounting data. The key problem in assessing efficiency is to evaluate how the various available resources (inputs) (financial resources, human resources, equipment, etc.) are used to achieve the set objectives (outputs) and how they should be used. Efficiency can be assessed in absolute or relative terms. In an absolute assessment, each unit is assessed individually without comparing it with other similar units. The evaluation may be based on known theory or on a belief (based on experience) about the unit's potential to perform. In the case of relative efficiency, the performance of other similar units is used as the basis for comparison. In this presentation, relative efficiency is considered.

Typically, efficiency assessment and efficiency planning aims to identify units that are underutilising resources and measure their degree of inefficiency, identify units that are fully efficient but "doing the wrong thing", allocate resources to productive areas, build new efficient units, etc.

Today, there is a great deal of research into the evaluation of efficiency and useful approaches have been developed. A common feature of these methods is that inputs and outputs are not "forcibly" combined, but considered as multidimensional quantities.

A very popular method of efficiency assessment is Data Envelopment Analysis (DEA). The method is the subject of a steady stream of scientific articles, but it has also been widely applied in practice. DEA was developed by Charnes, Cooper and Rhodes in 1978. It provides a straightforward way to distinguish between efficient and inefficient resource-using units. In addition, the analysis results in a numerical value for the degree of inefficiency of the inefficient units. This straightforwardness is an advantage in itself, but the disadvantage is the mechanical treatment of outputs and inputs. DEA analysis reveals general inefficiency, but not inefficiency where resources are used efficiently but for the wrong thing i.e. secondary outputs. This means that the analysis identifies as efficient units not only those that efficiently produce outputs that are perceived to be important, but also those that are capable of producing the maximum amount of outputs that are marginal to the firm. (Charnes, A., W. W. Cooper, A. Y. Lewin and L. M. Seiford, 1995)
Results of the efficiency assessment at Prisma

Technical efficiency was assessed by applying the traditional DEA analysis. The managers considered three outputs (sales, profit, sales margin) and three inputs (manhours and sales area m², value of stock) as appropriate measures to capture the multidimensionality of performance. As a result of the DEA analysis, 12 hypermarkets were found to be efficient and 17 inefficient. It was necessary to explain to managers the importance of technical efficiency, as it was not clear to them that technical efficiency did not mean that a hypermarket was operating at an "optimal" level from a management point of view.

We recommended that managers use value efficiency analysis as a method for analysing hypermarket performance, taking into account managers' preference information. Managers were asked to consider whether they could name a preferred hypermarket that could be used as a benchmark for hypermarkets. Their choice was a hypermarket in Jyväskylä (= the city of Central Finland). The hypermarket’s balance of performance factors best fitted the strategic definitions of the chain management. The analysis showed that 23 hypermarkets were inefficient in terms of value and only 6 were efficient in terms of value.

These hypermarkets were structured differently and managers were unable to rank the hypermarkets without help. Preference based ranking gave Prisma's management a concrete tool to understand how their hypermarket ranked among all hypermarkets in the chain and why.

The analysis was an important tool in the chain's strategic management, and the results enabled the chain's management to guide the managers of the units to act in accordance with the chain's strategic objectives.

2.6.2 Best practices within the chain

The second article "On the Use of Value Efficiency Analysis and Further Developments" discusses benchmarking between chain units. This article was produced in 2002 and is a continuation of the development process presented earlier. It has evaluated the efficiency of Prisma units with each other in the spirit of DEA and VEA. Twenty-eight units were included in the analysis and compared against each other using six common criteria.

This study also introduced the concept of Value Efficiency to the Prisma management, which at the time was a new and unique scientific offering for companies. In the report, it is shown how Value Efficiency can be used to identify new areas for development based on the desire to use a unit as a reference (target unit) during development.

2.7 Final review of the Competition Strategy

This dissertation describes how the Decision Support Approach has been successfully used to develop a competitive strategy for the Prisma chain. Management was looking for a new and sustainable operating model for a rapidly growing chain. Fierce competition forced the company to look for new
business ideas, tools and methods that would provide a clear competitive advantage.

To find new perspectives, we used statistical approaches, multivariate methods and various Decision Support Systems, mostly produced inhouse. For research and analysis, a survey database was available, including data on purchasing behavior and key performance indicators.

The approach took into account the role and impact of customers. Customer behavior was included in the analyses through shopping basket and customer listening data. From these, large datasets were created in the research database to combine the data using BigData-type data mining.

The implementation of Prisma's competition strategy was a long process, which at different stages required the use of imagination, skills, knowledge and a strong team spirit to achieve the objectives.

The main stakeholders in the implementation of the competition strategy were chain management, unit management, operational actors in the units, domestic and foreign suppliers and customers. Each stakeholder group had its own goals and views on how to act as part of the chain. The groups had to be made to work together in line with the goals of the competition strategy and this required constant interaction between the different parties. Feedback, ideas and comments on the strategy plans, reports and various comments were gathered and used to support development. This interaction helped to create the spirit of daring and willingness to be involved in building the future of the chain.

To identify and profile the customer, a chain-wide customer listening system was developed to map customer perceptions, practices, expectations and experiences. The listening exercise was carried out over several years and a set of indicators and a measurement system was developed to support the strategy and monitor the effectiveness of the actions taken. This provided tools for chain management to review KPIs and customer satisfaction indicators at the same time.

The wide and open sharing of data and results with different stakeholders required a common presentation language, where all analyses, figures, tables, dependencies and models were put into a format that the recipient could understand. The Descriptive Analysis approach was used here, with the addition of a huge number of proprietary graphical and slide-based presentations. The information was disseminated through various media and customers were informed about the results of the surveys, for example on separate large scoreboards in the aisles of Prisma units.

Competition between units is an essential part of the inner workings of the chain. Chain-by-chain reporting always covered all the units in the chain and, when they were operating according to the chain concept, comparison between them was possible. Combining KPIs with the metrics generated by customer listening process created a whole new perspective for managing operations. It could be clearly demonstrated that increasing customer satisfaction and service perceptions also influences the values of the KPI indicators. The need to compete on customer satisfaction and service levels emerged. The monitoring
of customer behaviour and profiling over several seasons created a desire for development and improvement among stakeholders.

The new way of measuring enabled customer-oriented benchmarking of the units. "Why is my unit less efficient or my service perception lower than another unit in the chain"? To answer these questions, explanations were sought, ways of doing things better were developed and staff were trained to act accordingly. The benchmarking exercise provided new and different perspectives to guide and monitor the implementation of the competition strategy.

All this was summed up by Kari Huju, who acted as an operational expert throughout the process, in an interview in September 2021:

"In the development of the Prisma chain, we hit a wall when we had to clean up the units in the chain with the help of so-called hard values, KPIs. The next step was to start looking for competitive advantage factors in line with the competitive strategy, with similar assortment, claim, etc. factors compared to competing chains. There were no ready-made comprehensive methodological solutions to the challenge, especially as the aim was to develop a set of metrics that would work seamlessly from customer needs to individual areas of assortment and operations.

From this starting point, we set out, together with a methodological expert who had already worked successfully with us, to find new ways and methods to measure and develop our competitive strategy activities. This was pioneering work, with the challenges that goes with pioneering work, looking for tools and indicators that would have a positive steering effect on the development of customer-oriented activities in relation to the chosen competition strategy. We worked in partnership to find the best and most validated methods, the measurement results of which were used to find answers, not only to specific development issues, but also to create an effective development process for operational development in line with the competition strategy. Without this joint development work, the Prisma chain might have remained one of the indistinguishable chains from the others, but its success tells a different story."

3. Software production

The implementation of the competition strategy required a major effort. The entities in the chain were similar in structure, but their human capital was different. People possess different resources - knowledge and skills - to receive and understand the information provided. The main rule was to try to present everything in pictures and diagrams, not in numerical, unwieldy tables. This set high standards for the level of presentation of the information to be shared. All
results had to be presented in a precise way, so that the recipient understood what was at stake and how it applied to them, what the situation was and what further action was needed to achieve the objectives of the strategy. The results were presented in detail to those concerned and who had the opportunity to influence the state of affairs.

Reports were produced and shared with all stakeholders through automated analysis chains using off-the-shelf software. Each of these systems has its own macro language available for this task.

The use of the off-the-shelf software, the production of new software, the management of the analysis chains, the use of the methods and the data architecture were the responsibility of the author. Other resources were used for routine tasks and storage services.

### 3.1 Automatic reporting and analysis

*Statistica and StatBasic for elementary statistics*

Statistica is a suite of analytics software products and solutions developed by StatSoft. The software includes a range of data analysis, data management, data visualisation and data mining procedures, as well as a variety of predictive modelling, clustering, classification and exploration techniques. An essential part of the software is StatBasic, which allows for automated analysis and combination of analyses. (Statistica, Statsoft, 2021)

The Statistica software is made for the Windows platform. Its use in combination with MS Excel provided good possibilities for multivariate analyses for ad hoc type reviews. This was used for both unit and chain-wide analyses, seeking to understand the structure of the whole chain and to answer the numerous ”Why is this the case?” questions. Statistica allowed the results of the analysis to be presented in graphical output in a form that the recipient could understand.

*Survo software and Survo-automation with macros*

Survo software has an exceptionally long history: the first Survo was already in use in the 1960s. (Mustonen, S., 1992). Survo has evolved from the statistical software of the 1960s into a general-purpose environment, with current applications including.

The Survo software was used to produce extensive analysis chains and reporting packages for shopping basket analyses. Shopping basket data was collected and processed continuously for one year. During this period, analyses and reports were produced for the different units in daily, weekly and monthly summaries. Reporting consisted of basic statistics and multivariate analyses in numerical and graphical output.
Excel and VBA interface to perform customer listening

The implementation of customer listening required the production of extensive software. This is because the surveys, analyses, methodologies and personalisations according to customer needs required features that were not available through off-the-shelf software.

Certain platforms such as MS Windows, Survo, MS Excel and Visual Basic for Applications (VBA), Statistica and StatBasic were a good basis, but their macro software had to be fully deployed for automation, repetition, output, analysis and survey database processing.
3.2 Software production for ranking operations

The development of the chain required comparisons between the units to answer the question, why one unit is better or more efficient than another. Criteria were available from various sources of information, such as shopping basket, customer listening and KPI data. There was also a spirit of competition and comparison between the units, which was generated by the various ranking lists. Criteria were selected by the chain's management so that they were comparable between the units.

Spreadsheet software makes it easy to produce different listings by sorting the data by columns. The problem arises when you want to know the combined effect of several criteria. What is the correct order to describe the order of the interaction of, for example, four criteria.

The chain management asked the author for questions and views on criteria and their comparability as well as on multi-criteria sorting. To organise the data, we set out to develop new approaches to the ranking problem with Pekka Korhonen.

This eventually led to the article "Ordinal Principal Component Analysis: theory and an application", which is one of the articles in this dissertation. The article, its algorithms and software were implemented together with Pekka Korhonen. Prior to the publication of the article, the software was used as a tool for chain development in various forms. The software was developed with the Delphi application developer, Pascal and also used the MS Excel interface as an add-on.

The author also wrote a licentiate thesis “Multiple Criteria Ranking” at the Helsinki School of Economics 1997, using Prisma data as case material. (Siljamäki, A., 1997) The results, ideas and software were presented to the Prisma management, thus completing the chain management’s understanding of different ranking methods and the use of criteria to compare data with.

3.3 Software production for DEA/VEA Analysis

The key element of the competition strategy was to measure efficiency in different forms and across different factors. The Data Envelopment Analysis approach, which emerged in the late 1970s, was also considered for this purpose. It was used for various public comparisons. This also gave rise to the use of this method in the development of Prisma.

The proposed analysis includes Value Efficiency Analysis as an approach, which applies the ideas developed for Multiple Objective Linear Programming (MOLP) to Data Envelopment Analysis (DEA). Preference information is given through the desirable structure of input- and output-values. The same values can be used for all units under evaluation or the values can be specific for each unit. A decision maker can specify the desirable input- and output-values intuitively without any support or (s)he can use a multiple criteria support system to assist him/her to find those values on the efficient frontier.

DEA/VEA approach was also to be tested and evaluated in the development of Prisma chain. One of the results of this research was the article "On the Use of
Value Efficiency Analysis and Further Developments", which is article No. 2 of this publication.

For this article, the author developed Excel-based software to perform analyses with a good user interface. The first versions of the software were produced on the MS Excel platform, using MS Solver for linear programming tasks. Later, the software was further developed and then the platform used was MS Visual Studio, Visual Basic language as a programming tool. The system was programmed for Linear Programming using LPSolve5-FreeWare software. (LPSolve5, 2021)

The tool was used for various analyses for the management of the Prisma chain. These analyses sought and found answers about the chain's efficiency structures, the differences between units, and explanations of the areas where efficiency improvements could move the chain in a desirable direction.

One more extensive study - "Evaluation of overall efficiency in the Prisma chain" - was carried out in 1997 (Siljamäki, A. and Korhonen, P.,1997). This is a project report written for Prisma management

The need for this analysis was obvious and resulted in the production, first for Prisma, but later also for other projects, of quite comprehensive software for DEA/VEA analysis in MS Windows/Visual Studio environment. All software production was done by the author.

4. Choice of Methods

**Strategic analysis tools**

Strategic measurement has used multivariate methods for different purposes. Correlation analyses have been used for KPI ratio analyses and product associations, step-wise regression analysis has been used in explanatory modelling to investigate which business idea indicators explain customers’ overall perception of an entity.

These analyses have been ad hoc type reviews to verify the factors revealed by the analyses (Rencher, A.,1998). The methods used and developed in the three articles are discussed in more detail below.

4.1 Ordinal Principal Component Analysis

In this study we investigate the problem of ordering multivariate data. We propose the use of the so-called (first) ordinal principal component for this purpose. The ordinal principal component is defined as a new ordinal variable
which orders the sample observations in such a way that the sum of the squares of the (rank) correlation coefficients between the original variables and the ordinal principal component is maximal. The definition provides a direct way to estimate a rank order for multivariate observations and it is also applicable to variables measured only on ordinal scales. It is consistent with the usual definition of the principal component transformation in the sense that the sum of the (weighted) squares of the correlation coefficients between the original variables and the principal component is also maximal. Because the correlation coefficients (Spearman’s and Kendall’s rank correlation coefficients) can be defined for ordinal variables as well, the ordinal principal component can be defined without using any cardinal information.

The problem of ordering multivariate data can be expressed as follows. Given a sample \( X_1, X_2, \ldots, X_n \) we require an arrangement of the form \( X_i < X_j < \cdots < X_k \), where "<" is the symbol: less preferred to, and the subscripts \( i, j, \ldots, k \) range over mutually exclusive and exhaustive subsets of integers 1, 2, ..., \( n \).

Many authors (e.g. Kendall, 1966 and 1970; Bell and Haller, 1969; Barnett, 1976) have expressed a pessimistic view of finding a natural basis for ordering multivariate data. In spite of the lack of a holistic natural basis, Barnett (1976) has presented four methods for interpreting the symbol "<". He calls these methods “sub-ordering principles” and terms them as marginal ordering, reduced (aggregated) ordering, partial ordering and conditional (sequential) ordering. Mardia (1976) has further suggested the sub-classifying of the different types of reduced ordering. These two types might be "distance ordering" and "projection ordering". The former term refers to the use of any specific measure of distance with the idea of the form of the underlying population, while the latter one would include ordering the sample by using the first principal component (or higher), seriation, etc.

According to the above classification, we shall consider reduced ordering - in particular, projection ordering, and suggest the use of the so-called (first) ordinal principal component for this purpose. The (first) ordinal principal component will be defined as a new variable which specifies a rank order for the sample observations in such a way that the sum of the squares of the (rank) correlation coefficients between the original variables and the new one is maximal. This principle provides us with a direct way to estimate a rank order to multivariate observations instead of using an indirect method like the one based on the first principal component. In addition, it is applicable to ordinal variables as well, i.e. to the variables measured on ordinal scales.

When the variables are only ordinal, it makes no sense to estimate the first principal component as the linear combination of variables (with standardized weights) having maximal variance, because the linear combination of ordinal variables is not well defined. However, the first principal component has a property, which provides an analogous way to define the so-called ordinal principal component. The first principal component maximizes the weighted sum of squares of the correlation coefficients between the original variables and the first principal component. The sample variances are used as weights when the principal component transformation is applied to the variance-covariance
matrix. Using Spearman's and Kendall's rank correlation coefficients (see, e.g. Siegel, 1956) we can estimate the pairwise correlation coefficients for variables given on ordinal scales as well. The ordinal principal component will be defined as a new variable which orders observations in such a way that the weighted sum of squares of rank-correlation coefficients between the original variables and the new one is maximal.

A typical extension of the principal component analysis is to apply it to ordinal or even nominal variables with a purpose to produce a new variable on a metric scale which somehow represents all the original variables (see, e.g. Gifi, 1991). Our purpose is to develop a principal component technique which uses information included in ordinal variables and produces the result on an ordinal scale as well.

4.2 Data Envelopment Analysis and Value Efficiency Analysis

In this study we discuss the use of Data Envelopment Analysis (DEA) and Value Efficiency Analysis (VEA) in efficiency evaluation when preference information is taken into account. Value efficiency analysis is an approach, which applies the ideas developed for Multiple Objective Linear Programming (MOLP) to DEA. Preference information is given through the desirable structure of input- and output-values. The same values can be used for all units under evaluation or the values can be specific for each unit. Decision Maker (DM) can specify the input- and output-values subjectively without any support or (s)he can use a multiple criteria support system to assist him/her to find those values on the efficient frontier. The underlying assumption is that the most preferred values maximize the DM's implicitly known value function in a production possibility set or a subset. The purpose of Value Efficiency Analysis is to estimate the need to increase outputs and/or decrease inputs for reaching the indifference contour of the value function at the optimum.

Data Envelopment Analysis (DEA) developed by Charnes, Cooper and Rhodes (1978, 1979) has become one of the most widely used methods in operations research/management science. (Charnes, A., Cooper, W. W., Lewin, A. Y., and Seiford, L. M., 1995). A reason for this success is that DEA is a task-oriented approach and focuses on an important task: to evaluate Relative (Technical) Efficiency of comparable Decision Making Units (DMU) essentially performing the same task. Based on information about existing data on the performance of the units and some preliminary assumptions, the purpose of DEA is to empirically characterize the so-called Efficient Frontier (Surface) based on the set of available DMUs and to project all DMUs onto this frontier. If a DMU lies on the frontier, it is referred to as an efficient unit, otherwise inefficient. DEA also provides Efficiency Scores and Reference Units for inefficient DMUs. Reference units are hypothetical units on the efficient frontier, which can be regarded as target units for inefficient units. A virtual reference unit is traditionally found in DEA by projecting the inefficient DMU radially to the efficient frontier.
The original DEA is value-free. Efficiency evaluation is based on the data available without taking into account the decision-maker's (DM) preferences. All efficient DMUs are considered equally "good." However, if the efficient units are not equally preferred by the DM, it is necessary to somehow incorporate the DM's judgments or apriori knowledge into the analysis. A straightforward and widely used method has been to restrict possible values of the multipliers of so-called dual DEA-models. The first proposal made by Thompson et al. (1986). For review, see Allen et al. (1997) and Pedraja et al. (1997). Another approach is to explicitly or implicitly gather direct preference information about the desirable input and output-values of DMUs, and insert that information in a form or another into the analysis. For this approach, some ideas can be adopted from research carried out in the field of Multiple Criteria Decision Making (MCDM), especially in Multiple Objective Linear Programming (MOLP).

In MCDM (MOLP), one of the key issues is to provide a DM with a tool, which makes it possible to evaluate points lying on the efficient frontier. The result of this evaluation is usually a point (solution) on the efficient frontier, which pleases the DM most. The solution is called the DM's Most Preferred Solution (MPS). Joro, Korhonen, and Wallenius (1998) have shown that the MOLP- and DEA-models have a similar structure. Thus theory and approaches developed in MOLP for evaluating solutions on the efficient frontier can also be applied in DEA. We may search for solutions also on the efficient frontier in DEA.

The most preferred solution plays a key role in the approach developed by Halme, Joro, Korhonen, Salo, and Wallenius (1999) to incorporate preference information into DEA. The approach is called Value Efficiency Analysis (VEA). Value efficiency analysis is based on the assumption that the DM compares alternatives using an explicitly unknown but implicitly known value function. The unknown value function is assumed to be pseudoconcave and strictly increasing for outputs and strictly decreasing for inputs. It is assumed to reach its maximum at the most preferred solution on the efficient frontier. The purpose of value efficiency analysis is to estimate the need to increase outputs and/or decrease inputs for reaching the indifference contour of the value function at the optimum. Because the value function is not assumed to be known, the indifference contour cannot be defined precisely. However, the region consisting of the efficient points surely less or equally preferred to the most preferred solution can be specified. This region is used in Value Efficiency Analysis. (Korhonen, P., A. Siljamäki and M. Soismaa. 1998)
4.3 Multiple Objective Linear Programming and Pareto Race

To implement the competition strategy, it was decided to use DSS modelling in the spirit of marginal planning analysis. Marginal planning was carried out using multi-objective linear modelling, where the structure of the departments of the unit was planned within the framework of shopping basket data, KPI information and given boundary conditions.

A Multiple Objective Linear Program (MOLP) is written

\[
\begin{align*}
\text{Max } & \{ c_1^t x = z_1 \} \\
\text{Max } & \{ c_2^t x = z_2 \} \\
& \ldots \\
\text{Max } & \{ c_k^t x = z_k \} \\
\text{s.t } & x \in S
\end{align*}
\]

or

\[
\text{“max” } \{ Cx = z \ | \ x \in S \}
\]

where

- \( k \) is the number of objectives,
- \( c^i \) is the gradient (vector of objective function coefficients) of the \( i \)th objective function
- \( z_i \) is the value (objective function value, \( z \)-value) of the \( i \)th objective.
- \( S \) is the feasible region.
- “max” indicates that the purpose is to maximize all objectives simultaneously.
- \( C \) is the \( k \times n \) matrix of objective function coefficients, whose rows are the gradients \( c^i \) of the \( k \) objective functions.
- \( z \) is objective function vector.

Since multiple objective problems rarely have solutions that simultaneously maximize all of the objectives, we are typically in a situation of trying to maximize each objective to the “greatest extent possible”. To understand the difficulties that can be encountered in attempting to do this, we refer to topics of utility functions, nondominated criterion vectors, and efficient points introduced in (Steuer, R., 1989, pp. 138-139) and (Korhonen, P. and Wallenius, J., 2020).

For the marginal planning analysis model, a multi-objective linear model was used, where its structure followed the form:
Figure 7. DSS model structure for the Marginal Analysis problem

The model was used as a strategic planning tool. There was a need to interactively explore a range of rational solutions and make better decisions. The software chosen for this task was VIG (Visual Interactive Goal Programming), developed by Pekka Korhonen. This software uses the Pareto Race method (Korhonen and Wallenius, 1988). VIG allows decision makers to move freely on a non-dominated surface and search for their own most desired solutions.

The operational team learned how to process the data themselves using MS Excel and the available modelling tools (VIG). The team also prepared presentation material for the decision-making bodies.

Figure 8. Pareto Race in Marginal Analysis

In the example above, three objectives are considered at the same time. The objectives and their values can be varied and thus solutions can be viewed from different perspectives. During the Pareto Race process, the user’s eyes were "opened" to the reality embodied in the model. First there is admiration, then confusion and finally a realization: “Can this be real?” The interdependencies of the model told the user the efficiency of the actions in a "what-to-do-to-
achieve” or "what-if" analysis and broadened the view for a strategy-type discussion (Huju, K. 2021, Mönkkönen, H., 2021).

The collaboration of the DSS design team highlighted that understanding, using and benefiting from a decision support system are different things. A model can be understood and accepted without knowing how to use it or even wanting to use it.

5. Summary of articles

5.1 Ordinal Principal Component Analysis: Theory and an Application

In this article, we examine the Prisma chain in its entirety through an interunit comparison using four different criteria on an ordinal scale. In the article we consider the problem of ordering multivariate data. For this purpose, we propose the use of the so-called (first) ordinal principal component. The ordinal principal component is defined as a new ordinal variable that orders the sample data such that the sum of squares of the correlation coefficients between the original variables and the ordinal principal component is the largest. This definition provides a straightforward way to estimate the ordering of multivariate observations and can also be applied to variables measured only on an ordinal scale. It is consistent with the usual definition of principal component transformation in the sense that the sum of the squares of the (weighted) correlation coefficients between the original variables and the principal component is also maximum. Since correlation coefficients (Spearman and Kendall correlation coefficients) can also be defined for ordinal variables, the ordinal principal component can be defined without cardinal data.

However, the result of our study in this article suggests that the units can be arranged in a better order if we use the ordinal principal component analysis we propose. Based on the basic solution, we were able to show a new ordering that is fundamentally more correct for the units in the sense that the final ordering it produces is more correct from the ordinality point of view.

5.2 On the Use of Value Efficiency Analysis and Further Developments

In the second article, we evaluate the units in the chain from the point of view of efficiency. The same criteria are used as in the first article, but this time the original values are used for efficiency measurement. In addition, the number of
units has been increased to 25. The article discusses the use of Value Efficiency Analysis (VEA) to assess efficiency when taking into account preference data. Value efficiency analysis is an approach that applies ideas developed for Multi-Objective Linear Programming (MOLP) to the comparison of units in terms of efficiency (DEA). Preference information is provided through the desired input and output values. The same values can be used for all units under evaluation or the values can be unit specific. The decision maker can determine the input and output values subjectively without support, or he can use a multi-criteria support system to help him find the values at the efficiency frontier. The underlying assumption is that the preferred values maximize the value function implicitly known to the decision maker among a set or subset of production possibilities.

The purpose of value efficiency analysis is to assess the need to increase outputs and/or reduce inputs in order to achieve the optimal indifference contour of the value function. The study briefly reviews the main ideas behind value-added analysis and discusses the practical aspects of using value-added analysis. We also consider some extensions.

5.3 A Decision Support Approach to achieve Competitive Advantage for a Hypermarket Chain

This article deals with a situation where the main objective of the process was to develop a competition strategy that would give the Prisma chain a long-term competitive advantage. In order to find new perspectives, we decided to use statistical approaches and different decision support system options, such as multi-criteria modelling. For the research and analysis, a database of data on shopping behavior and key performance indicators (KPIs) was available.

The approach had to take into account the role and impact of customers. It was crucial to include customer behavior in the analysis through shopping basket data. Shopping basket data was central to this paper. It was used to create an observation matrix combining shopping basket data, product data and customer background information. Using multivariate methods, customer groupings and profiles were created using the data from the observation matrix. The customer profile and KPI data were used to produce a Multi-Criteria Decision Support System (MCDSS) to support strategic planning.

To support the strategy work, different models were developed and used to analyse and study the data collected, prioritise and select decision options. Two currently retired managers (Mönkkönen and Huju, 2021), who were involved in the development process, rated the strategy process as very successful and the modelling carried out during the process significantly supported decision-making. The immediate help of DSS modelling in decision making comes from its ability to provide decision makers with rational, better solution options to support their decision making. The final impact of decisions could be assessed over a longer period of time, which in the case of the Prisma development project results means several comparable financial years. Finland was exceptionally hard hit by the financial crisis and the global economic downturn
in 2008-2009. The Prisma chain has survived the periods and crises described above without any lossmaking years, and the whole chain has grown from 16 units in 1992 to 68 units in 2020.

REFERENCES


Internet references:

Interviews: