NTNU – Trondheim
Norwegian University of
Science and Technology

Logistics Planning Module for Microsoft AX: Demand Planning

Alexey Lekanov

Master of Science in Engineering and ICT
Submission date: June 2012
Supervisor: Erlend Alfnes, IPK
Co-supervisor: Odd Jøran Sagegg, Logica

Norwegian University of Science and Technology
Department of Production and Quality Engineering

NTNU

Fakultet for ingeniørvitenskap og teknologi
Institutt for produksjons- og kvalitetsteknikk

Vår dato 2012-01-12
Vår referanse EAL/LMS

MASTEROPPGAVE
Våren 2012
for
stud. techn. Alexey Lekanov

LOGISTIKK PLANLEGGINGS MODUL FOR MICROSOFT AX: DEMAND PLANNINIG

(Logistics Planning Module for Microsoft AX: Demand Planning)

Logica er et selskap som leverer tjenester og teknologi for forretningsdrift, og har ca 40 000 ansatte på verdensbasis. Selskapet er ledende i Norge innenfor rådgivning, systemintegrering og outsourcing for alle bransjer og forretningsfunksjoner. Oppgaven vil løses i tett samarbeid med Logicas ERP avdeling som ønsker å videreutvikle funksjonaliteten i Microsoft Dynamics AX på en rekke områder i samarbeid med norsk industri.

ERP systemer har varierende støtte for prognostisering. Microsoft Dynamics AX innehar støtte for bearbeiding av prognoser, men systemet støtter ikke generering av nye prognoser ut fra for eksempel historiske salgsdata. Det er derfor utviklet flere tredjepartsystemer for å generere prognoser til Microsoft Dynamics AX. Disse henter historiske salgsdata ut fra systemet for så å bearbeide disse til fremtidige prognoser, gjennom bruk av algoritmer som glidende gjennomsnitt og eksponentiell glatting. I tilegg kan systemene generere prognoser ved å hente forespeilet salgsdata fra ulike aktører i leveransekjeden (collaborative planning).

Oppgaven består i å utvikle et verktøy for prognostisering i ERP systemet Microsoft Dynamics AX. Det skal utvikles funksjonalitet for prognostisering basert på historiske data og samarbeidsorienterte modeller. Datagrunnlaget skal hentes fra ERP systemet eller andre relevante kilder og det skal være mulig å oppdatere parametre i systemet ut fra forbedringsforslaget som genereres. Det skal utvikles et funksjonelt og teknisk design for et slikt verktøy. Løsningen bør være nettbasert og være bygd på standard Microsoft teknologi.

Studenten skal besvare følgende spørsmål:

1. Gi en oversikt over relevant teori og best practices innen prognoseplanlegging og demand planning.
2. Lag en overordnet kravspesifikasjon for prognosefunksjonalitet og demand planning.

3. Undersøk eksisterende funksjonalitet, samt muligheter og begrensinger for prognostisering i AX2012.
4. Spesifiser overordnet produktorientert kravspesifikasjon for ny prognostiseringsmodul i AX2012.
5. Lag brukerorientert løsningsdesign for ny prognostiseringsmodul i AX2012.
6. Lag utviklingsdokumentasjon (Functional Modification Specification's) til ny prognostiseringsmodul i AX2012.
7. Lag prototype på utvalgt funksjonalitet i AX2012

Oppgaveløsningen skal basere seg på eventuelle standarder og praktiske retningslinjer som foreligger og anbefales. Dette skal skje i nært samarbeid med veiledere og fagansvarlig. For øvrig skal det være et aktivt samspill med veiledere.

Innen tre uker etter at oppgaveteksten er utlevert, skal det leveres en forstudierapport som skal inneholde følgende:

- En analyse av oppgavens problemstillinger.
- En beskrivelse av de arbeidsoppgaver som skal gjennomføres for løsning av oppgaven. Denne beskrivelsen skal munne ut i en klar definisjon av arbeidsoppgavenes innhold og omfang.
- En tidsplan for fremdriften av prosjektet. Planen skal utformes som et Gantt-skjema med angivelse av de enkelte arbeidsoppgavenes terminer, samt med angivelse av milepæler i arbeidet.

Forstudierapporten er en del av oppgavebesvarelsen og skal innarbeides i denne. Det samme skal senere fremdrifts- og avviksrapporter. Ved bedømmelsen av arbeidet legges det vekt på at gjennomføringen er godt dokumentert.

Besvarelsen redigeres mest mulig som en forskningsrapport med et sammendrag både på norsk og engelsk, konklusjon, litteraturliste, innholdsfortegnelse etc. Ved utarbeidelsen av teksten skal kandidaten legge vekt på å gjøre teksten oversiktlig og velskrevet. Med henblikk på lesning av besvarelsen er det viktig at de nødvendige henvisninger for korresponderende steder i tekst, tabeller og figurer anføres på begge steder. Ved bedømmelsen legges det stor vekt på at resultatene er grundig bearbeidet, at de oppstilles tabellarisk og/eller grafisk på en oversiktlig måte og diskuteres utførlig.

Materiell som er utviklet i forbindelse med oppgaven, så som programvare eller fysisk utstyr er en del av besvarelsen. Dokumentasjon for korrekt bruk av dette skal så langt som mulig også vedlegges besvarelsen.

Eventuelle reiseutgifter, kopierings- og telefonutgifter må bære av studenten selv med mindre andre avtaler foreligger.

Hvis kandidaten under arbeidet med oppgaven støter på vanskeligheter, som ikke var forutsett ved oppgavens utforming og som eventuelt vil kunne kreve endringer i eller utelatelse av enkelte spørsmål fra oppgaven, skal dette straks tas opp med instituttet.

Oppgaveteksten skal vedlegges besvarelsen og plasseres umiddelbart etter tittelsiden.

Innleveringsfrist: 11. juni 2012

Besvarelsen skal innleveres i 1 elektronisk eksemplar (pdf-format) og 2 eksemplar (innbundet).

Ansvarlig faglærer ved NTNU: Erlend Alfnes
E-post: erlend.alfnes@ntnu.no
Telefon: 73 59 71 22
Mobiltelefon: 982 91 145

Veileder ved Logica: Odd Jøran Sagegg
E-post: odd.joran.sagegg@logica.com
Mobiltelefon: 919 14 819

INSTITUTT FOR PRODUKSJONS- OG KVALITETSTEKNIKK

Per Schjølberg
Per Schjølberg
førsteamanuensis/instituttleder

Erlend Alfnes
Erlend Alfnes
faglærer

Preface

This report is the result of master thesis “Logistics Planning Module for Microsoft AX: Demand Planning” carried out at the last semester of the fifth year of study at master’s degree program *Engineering and ICT* at *Norwegian University of Science and Technology* (NTNU). The thesis was performed at *Department of Production and Quality Engineering* (IPK) as course TPK4900.

The thesis’ assignment was developed by IPK in close collaboration with *Logica*, business and technology service company, which experience deficit of functionality at certain modules in the ERP system Microsoft Dynamics AX currently being offered, among others, to Logica’s clients in Norway. The company wishes to develop the missing functionality.

I would like to thank my responsible teacher and supervisor at IPK, Erlend Alfnes, for the guidance and help during the thesis, as well as Emrah Erica, Marco Semini and Cecilia Haskins for the advices during my work. I would also like to thank Logica Norway and especially its employee and my supervisor, Odd Jøran Sagegg, for the guidance and valuable materials provided to assist me with the thesis. In addition I would like to express my gratitude to the Norwegian companies and their employees, especially Vegard Arnegård and Espen Orderud from *Flexit*, who kindly agreed to answer my questions and which answers were of great help. The last thanks go to my friends, comrades and fellow students for the motivation and support during the conduction of this master thesis.

Trondheim, 11.06.2012

____

Stud. techn. Alexey Lekanov

Summary

One could hardly find a person who would disagree that the information technology is essential part of any business today. In the same way it is known how a proper demand planning process can assist an organization in making correct decisions at the right time and is therefore also vital for its success. Having all this in mind, one could expect the modern IT systems to have a good support for demand planning, but this is not always the case, like it is with the ERP system Microsoft Dynamics AX 2012. This ERP system has only limited support for forecasting, and Logica, a consultancy company offering among others Dynamics AX to its customers, in collaboration with Norwegian University of Science and Technology (NTNU), would like to develop this functionality seamlessly built into AX 2012.

This master thesis is about making a research at the demand planning and supply chain management fields in order to identify current state-of-the-art demand planning process and requirements specification for a Demand Planning Module to support such process, and, based on this, find a way to seamlessly build Demand Planning Module's functionality into AX 2012 with all the benefits such smooth integration provides.

The research presented in this work, provides first a short presentation of ERP systems and their disability to properly support supply chain management, concluding with remarks about ERP II vision being an attempt to counter this disability. Microsoft Dynamics AX 2012 and its insufficient demand planning functionality are then specifically addressed. After that the demand planning field is studied, a common demand planning framework is proposed. The framework describes the entire, what is believed, state-of-the-art demand planning process including (i) understanding of purpose, benefits and conditions of demand planning process, (ii) structuring data in a way that a quality forecasting process can be run, (iii) the forecasting process itself which uses qualitative, quantitative and collaborative approaches and (iv) critically reviewing and analyzing the demand planning process and looking for the ways to improve it. Afterwards, a short classification of forecasting methods is presented, dividing the methods into qualitative and quantitative, where the latter ones are further partitioned into naïve, time-series, causal and simulation. Some of the forecasting techniques are described in details while others are briefly presented. It is also shown that forecasts are always wrong and there is a need for error metrics to evaluate the forecasts' performance; the most common metrics are described.

This theory study, and first and foremost the common framework, results in a generic requirements specification for Demand Planning Module, which is then compared to the AX 2012 forecasting functionality. Many functional gaps are identified by this comparison and an attempt to solve them via developing user-oriented solution design and corresponding functional modifications specifications is given. The attempt, though, proved to have strong limitations in form of the author's insufficient training and in-depth understanding of AX 2012 and its processes' correlation to each other.

Sammendrag

Man kan knapt finne en person som vil være uenig i at informasjonsteknologien er en essensiell del av enhver bedrift i dag. På samme måte er det kjent hvordan en skikkelig prognostiseringsprosess kan bistå en organisasjon med å gjøre riktige beslutninger til rett tid og er derfor også viktig for dens suksess. Når man har alt dette i bakhodet, kan man forvente at moderne IT-systemer har en god støtte for prognostisering, men dette er ikke alltid tilfelle, slik det er med ERP-systemet Microsoft Dynamics AX 2012. Dette ERP-systemet har bare begrenset støtte for prognoser, og Logica, et konsulentselskap som tilbyr blant annet Dynamics AX til sine kunder, i samarbeid med Norsk teknisk-naturvitenskapelige universitet (NTNU), ønsker å utvikle denne funksjonaliteten slik at den blir sømløst innebygd i AX 2012.

Denne masteroppgaven handler om å foreta en forskning på områdene prognostisering og verdikjedestyring for å identifisere nåværende «state-of-the-art» prognostiseringsprosess og kravspesifikasjon for en prognostiseringsmodul som kan støtte en slik prosess, og, basert på dette, finne en måte å sømløst innebygge prognostiseringsmodulens funksjonalitet inn i AX 2012 med alle fordelene som smidig integrasjon gir.

Forskningen presentert i dette arbeidet, gir først en kort presentasjon av ERP-systemer og deres manglende evne til å tilby en akseptabel støtte til verdikjedestyring, konkluderer med bemerkninger om ERP II visjon som et forsøk på å motvirke denne uførheten. Microsoft Dynamics AX 2012 og dens manglende prognosefunksjonalitet blir deretter nøyere beskrevet. Etter at feltet prognoseplanlegging er undersøkt, er en såkalt «common demand planning framework» foreslått. Rammeverket beskriver hele, og det antas, «state-of-the-art» prognoseplanleggingsprosessen inkludert (i) forståelse av formål, fordeler og betingelser for prognoseplanlegging, (ii) strukturering av data på en sånn måte at en kvalitetssikker prognoseringsprosess kan kjøres, (iii) selve prognoseprosessen som bruker kvalitative, kvantitative og samarbeidsorienterte tilnærminger og (iv) kritisk gjennomgang og analyse av prognoseplanleggingsprosessen og søket etter måter å forbedre den på. Etterpå blir en kort klassifisering av prognosemetodene presentert. Den klassifiserer metodene som kvalitative og kvantitative, der sistnevnte de er videre delt opp i naive, tidsserier, kausale og simulering. Noen av prognoseteknikkene er beskrevet i detalj, mens andre blir kort presentert. Det er også vist at prognosene alltid tar feil, og det er et behov for feilberegninger for å vurdere prognosenes prestasjoner, de vanligste beregningene er beskrevet.

Dette teoristudiet, og først og fremst «common framework», resulterer i en generell kravspesifikasjon for prognostiseringsmodulen, som deretter sammenlignes med AX 2012 sin prognosefunksjonalitet. Mange funksjonelle hull identifiseres med denne sammenligningen, og et forsøk på å løse dem via utvikling av brukerorientert løsningsdesign og tilhørende utviklingsdokumentasjon er gitt. Forsøket viste seg å ha sterke begrensninger i form av forfatterens mangelfull opplæring og grundig forståelse av AX 2012 og dets prosessers korrelasjon med hverandre.

Table of Content

Figures

Tables

Abbreviations

General

AI	Artificial intelligence
AIF	Application Integration Framework
APICS	The Association of Operations Management
	(formerly: American Production and Inventory Control Society)
BI	Business intelligence
BOM	Bill of materials
BOMP	Bill of materials processor
CL-MRP	Closed-loop material requirements planning
CPFR	Collaborative planning, forecasting and replenishment
CRM	Customer relationship management
ERP	Enterprise resource planning
ES	Enterprise system
FMS	Functional modification specification
IPK	Department of Production and Quality Engineering
	(Norwegian: Institutt for produksjons- og kvalitetsteknikk)
IS	Information system
MRP	Material requirements planning
MRP II	Manufacturing resource planning
NTNU	Norwegian University of Science and Technology
	(Norwegian: Norges teknisk-naturvitenskapelige universitet)
SCM	Supply chain management
XML	Extensible markup language

Forecasting

APA	Absolute percentage accuracy
APE	Absolute percentage error
ARMA	Autoregressive moving-average
ARIMA	Autoregressive integrated moving-average
FVA	Forecast value added
MAD	Mean average deviation
MAPE	Mean absolute percentage error
MAPA	Mean absolute percentage accuracy
MSE	Mean squared error
TS	Tracking signal

1 Introduction

This chapter in meant to introduce the research topic of the thesis and motivation behind it. It will also define the problem and present thesis' goals, providing a description of report structure at the end.

1.1 Background and Motivation

Information technology and business are becoming inextricably interwoven. I don't think anybody can talk meaningfully about one without the talking about the other.[1]

Bill Gates

In modern reality business and technology cannot exist separately; a firm's business strategy drives its information strategy as well as its organizational strategy, while the information strategy in turn affects both other strategies (Pearlson and Saunders, 2009). Choosing an enterprise system (ES) is therefore a strategic choice vital for a firm's success. From material requirements planning (MRP) and manufacturing resource planning (MRP II), the enterprise resource planning (ERP) systems have arisen as the most frequently discussed type of ES. ERPs are able to turn organization's different functional units from separate silos into one integrated environment with smooth information flow and standardized processes supported by industry's best practices. Right choice of an ERP system is therefore a vital decision for any organization.

Chopra and Meindl (2010) states no less than *"the forecasting module is one of three core products around which the entire supply chain software industry grew"*. Even not going this far at estimating forecasting (or demand planning) module's importance, it is known that a lot of decisions in an enterprise, especially a manufacturing one, are dependent on forecasts, e.g. security stock level, procurement of raw materials, production and financial planning etc. In these circumstances one would expect any major ERP system to support such functionality. This is indirectly supported by the fact that major ERP suppliers like SAP and Oracle offers forecasting modules to their customers (Chopra and Meindl, 2010). Still, the usefulness and user-friendliness of these modules can be questioned since there are many third-party systems like *SAS Forecasting for SAP APO*, TXT e-Solutions' *Demand Planner* for Microsoft Dynamics AX etc., offering additional forecasting and demand planning functionality to the ERP systems. Oracle's acquisition of Demantra, "leading global provider of demand-driven planning solutions" (Oracle, 2006), is an indication of the ERP suppliers' attempts to fix this functional deficiency.

Microsoft with its ERP system, having the third largest ERP market share in the world (Burnett, 2011), and, according to my supervisors, being number one in Norway, where this thesis is conducted, does not currently offer a Demand Planning Module for its *Microsoft Dynamics AX 2012* (from now on also referred to as *Dynamics AX* or *AX 2012*). The Microsoft licensed Demand Planner for Dynamics AX from TXT e-Solutions was announced to be discontinued (Butt, 2009) so that currently no Microsoft demand planning solutions for Dynamics AX exist, except the inadequate functionality built-in in AX 2012 by default. The ERP system itself has limited support for demand planning: according to the thesis' supervisors and the assignment's text itself, AX 2012 is only able to process already completed demand forecasts imported for example from Excel documents, but it is unable to make forecasts by itself. This seems to be a situation where no software vendor offering AX 2012 to its customers wants to be placed in. Logica, being a large business and technology service company, is such a vendor and it is one of the stakeholders and a collaborative partner at this thesis, which is an extension of the previous semester's

[1] http://www.woopidoo.com/business_quotes/authors/bill-gates-quotes.htm

work of the same author, Lekanov (2011), which, in turn, is a continuation of the study performed by Roar Kahrs Vik (Vik, 2010). While the specialization project from the previous semester had developing of generic requirements specification for a Demand Planning Module as its final goal, the ultimate goal of this thesis is describing an opportunity to build the required functionality directly into the AX 2012 with all the advantages over the third-party module development this approach provides.

1.2 Problem Statement and Scope

The original problem statement is defined in the assignment text in the following way:

"The task consists of developing a tool for forecasting in ERP system Microsoft Dynamics AX. There should be developed functionality for forecasting based on historical data and collaborative models. The data are retrieved from the ERP system or other relevant sources, and it should be possible to update the parameters of the system from the improvement proposal which is automatically generated. There should be developed a functional and technical design for such a tool. The solution should be web-based and be built on standard Microsoft technology."

The tasks are stated as following:

1. Provide an overview of relevant theory and best practices within forecasting and demand planning.
2. Create a general requirements specification for forecasting and demand planning functionality.
3. Examine the existing functionality, as well as opportunities and limitations of forecasting in AX 2012.
4. Specify the overall product-oriented requirements specification for the new Demand Planning Module in AX 2012.
5. Create user-oriented solution design for the new Demand Planning Module in AX 2012.
6. Create development documentation (Functional Modification Specifications) for the new Demand Planning Module in AX 2012.
7. Create prototype on chosen functionality in AX 2012.

As it comes from the tasks above, objectives of this thesis is to identify current best practice demand planning process, develop requirements specification for a software system that is able to support that process and find a way to build these requirements into AX 2012. This leads us to three research questions (RQs):

- RQ1: *What is the current state of the art demand planning and forecasting process?*
- RQ2: *What are the requirements for Demand Planning Module which is able to support the current state of the art demand planning process?*
- RQ3: *Which of the requirements from RQ2 are relevant for Microsoft Dynamics AX 2012, and how can they be implemented in the ERP system?*

A literature study within the fields of demand planning and supply chain management must be conducted to answer RQ1. Then, based on the answer on RQ1, the solution of RQ2 can be found. The final research question (RQ3) can then be answered on the basis of RQ2-solution and the analysis of AX 2012, which will be a part of literature study.

Due to the fact that the required functions are not to be built as third-party software, but rather be a seamless part of AX 2012, the design and implementation of huge AX-wide features like web-functionality and integration support are not considered as a part of Demand Planning Module and are left to Microsoft. Another consequence of this approach is that the solution will be built on AX 2012 architecture, and technical specification of how the solution will work and communicate with the ERP system is therefore not required. Totally we see that the benefits of this approach are many: No-effort integration with ERP system and its data, the same user interface in the Demand Planning Module and the rest of the system, no external application to install and maintain etc.

Originally, it was planned to create a static prototype illustrating proposed demand planning functionality, however, during the thesis' execution after discussions with my supervisors, especially with Odd Jøran Sagegg from Logica, the goal about creating a prototype was omitted. There were two reasons for that. First reason is the task formulated the way it is necessary to build new functionality into AX 2012, i.e. customize the system, it will then be waste of time and effort to program the same functionality and interface outside of the system. The second reason is the typical structure of user-oriented solution design and corresponding functional modification specifications which are meant to be illustrative enough for users and developers to understand how future ERP-supported processes will happen and how the interface will look like, so that a need of a static prototype for illustration purposes is absent.

1.3 Thesis' Goals and Success Criteria

The thesis' goals and success criteria remain the same as at the beginning of the thesis as stated in *Appendix A: Preliminary Report*.

The goals for this thesis are:

- Successfully answer all the research questions
- Greatly contribute to Logica's effort to develop additional demand planning functionality for Microsoft Dynamics AX 2012
- Get an even deeper understanding of the main topics of this thesis and in this way prepare for the future career
- Train to work evenly, systematically and scientifically
- Try out what a "real life" tasks might look like and train to solve them

The thesis can be considered fully successful if all the following criteria are met:

- Grade B or better
- Positive feedback from the supervisors
- The thesis' result is considered a very significant improvement of the foregoing specialization project from the previous semester
- Feeling of a well-accomplished task
- Feeling of being well-prepared for the future career in this field

1.4 Report Structure

The report is divided into 8 main chapters which are presented below as a list with short description of chapters' main content:

1. *Introduction*, introducing reader to the topic, describing the tasks at hand and the thesis' goals.
2. *Research Methodology*, describing methodologies and methods used in this thesis.
3. *Literature Study*, consisting of a description of ERP systems generally and their role in supply chain management, then providing a generic description of AX 2012 and its forecasting functionality. The last part of the chapter describes what is considered a "best practice" demand planning process and provides an overview of forecasting methods and error metrics. This chapter answers RQ1.
4. *Developing Software Requirements*, shortly describing how the requirements were gathered.
5. *Demand Planning Module Requirements Specification*, consisting of the generic and AX 2012 specific requirements specifications, answering RQ2 and the first part of RQ3.
6. *Developing User-oriented Solution Design*, presenting the phases of creating user-oriented solution design at Logica and this work's relation to that process.
7. *User-oriented Solution Design*, consisting of base solution, i.e. description of managing demand planning process in AX 2012, and functional modification specifications needed for Dynamics AX to support that process. This chapter answers the last part of RQ3.
8. *Industry Opinion*, presenting the results of interviews with a couple of Norwegian companies about their opinion on required functionality for a demand planning system.
9. *Conclusion*, discussing and summing up the results as well as suggesting further research direction.

2 Research Methodology and Methods

Given the problem at hand and the thesis' goals, it is now required to choose an appropriate research methodology and find out what kind of research methods to use in this thesis. First of all the difference between the terms *methodology* and *method* must be clarified. According to (Sachdeva, 2009) a method is a concrete technique for gathering evidence/information while methodology is the underlying theory and analysis of how research does or should proceed. Let us consider methodology first.

It is common to distinguish between *qualitative* and *quantitative* research methodologies (Dhawan, 2010, Phophalia, 2010). Quantitative research is being based on quantifiable data: measures, numbers, amount etc., while qualitative research is based on data which cannot be quantified. Dhawan (2010) distinguishes further between *applied* and *fundamental* research, where the applied one is aimed at certain conclusion or solution while fundamental is mostly about generalizations and formulation of a theory.

Research methodology used in the first part of this thesis can be classified as qualitative, applied research since it is dealing with unquantifiable data (frameworks, processes and theories) and results in a concrete solution to the real world problem at hand.

Roughly speaking, this thesis can be divided into two parts: The first one is classical literature study and the second one is system development. It is the second part that deserves more attention when it comes to calling it an academic research: System development seems to add no new knowledge, but rather use the results achieved by research in various field. However, Nunamaker Jr. and Minder (1990) argues that *the systems development methodology is an age-old method and process that human beings use to study nature and to create new things*, then providing numerous examples of systems development contributing to several research domains and therefore adding new knowledge. Furthermore, the research questions in this thesis are formulated the way that they require running a system development process to be answered. It can therefore be said that research methodology used when creating requirements specifications and user-oriented solution design with functional modification specifications is system development.

2.1 Literature Study Method

Having in mind the research questions from section *1.2 Problem Statement and Scope* as a guideline for this work, it is no surprise that finding, studying and analyzing of literature has been the starting point of this thesis. First of all there was a need to get a general understanding of the fields of study, that is where the finding and studying of the relevant literature comes into play. Predominantly the NTNU's resources has been used for finding the literature: Universitetsbiblioteket's *BIBSYS Ask* and *Google Scholar* search engines which provided the opportunity to search for electronic and journal articles, whitepapers, books etc., which are either freely accessible over the internet or are accessible for the NTNU students and employees. Following keywords have been used for finding the relevant literature: forecasting, forecasting method, demand planning, ERP systems, SCM, CPFR, collaborative planning, e-business and supply chain integration. Preliminary studying of the found sources has occurred by reading the abstract and, if the material seemed to be of interest, also introduction and conclusion in order to estimate the relevance of the given source more precisely. Further studying and analyzing of the sources found relevant, has involved much more thorough study of these sources as well as taking notes on the points especially applicable for the thesis. Analyzed results were then presented in the *Literature Study* chapter of this report.

2.2 Requirements Specification Development Method

The method of gathering software requirements for the Demand Planning Module is described in more details at chapter *4 Developing Software Requirements*. Generally, it was planned that the requirements would become clear through conduction of the literature study and gaining deeper understanding of the fields.

2.3 User-oriented solution design Development Method

The method, called *FremDrift*, for developing user-oriented solution design and this work's role in the method is presented in chapter *6 Developing User-oriented Solution Design*. In general, it can be mentioned that the development of user-oriented solution design and corresponding functional modification specifications was enabled through conduction the literature study, developing requirements specifications and analyzing AX 2012.

3 Literature Study

Current chapter contains the essence of the relevant literature studied under this thesis. Having the thesis' goals in mind, it will start with an introduction to ERP systems generally and their contribution at the field of supply chain management, describing also Microsoft Dynamics AX more specifically. Afterwards, demand planning as a process will be described as well as various forecasting methods and error metrics. The chapter will conclude with discussion of the literature findings and possible ways to further improve the literature review.

3.1 ERP Systems and their Place in Supply Chain Management

ERP is an acronym which stands for *enterprise resource planning* and is defined as *"framework for organizing, defining, and standardizing the business processes necessary to effectively plan and control an organization so the organization can use its internal knowledge to seek external advantage"* by the APICS dictionary (Blackstone Jr. and Cox, 2005). ERP is an information system (IS) that is intended to seamlessly integrate the flow of information throughout an enterprise and support and standardize the enterprise's functions. In practice it is a sophisticated software system consisting of several modules build around one central database, see Figure 1.

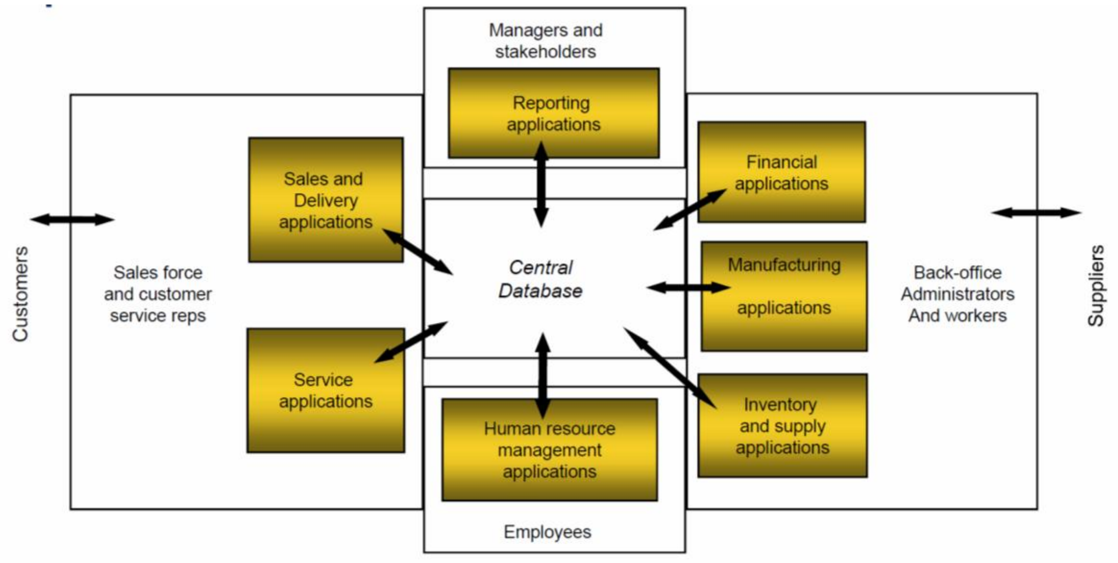


Figure 1: Anatomy of an enterprise system (Davenport, 1998)

Modules of an ERP system are designed to support enterprise functions, some of them being core functions common for the most of the industries (these are shown on the figure above), and the others being more specialized industry specific functions. All modules are typically designed to have similar user interface to facilitate ease of user learning since modern ERP systems are usually very sophisticated and require extensive training of users to be utilized effectively and efficiently.

A historical perspective on the development of ERP systems will be presented next as well as a short description of a specific system which this thesis is about, namely Microsoft Dynamics AX 2012.

3.1.1 Historical Perspective and typical Functions of ERP Systems

Late 1950s and 1960s are often perceived as the years when the basic structure of ERP functions was originated (Bititci, 2003, Moller, 2005, Jacobs and Weston Jr, 2007). A description of historical development of enterprise resource planning software often begins with mentioning MRP (material requirements planning) as the starting point, then describing MRP II (manufacturing resource planning) and finally passing to the ERP systems themselves. Alfnes (2011) presents a more fine-grained retrospective overview which is shown at Figure 2.

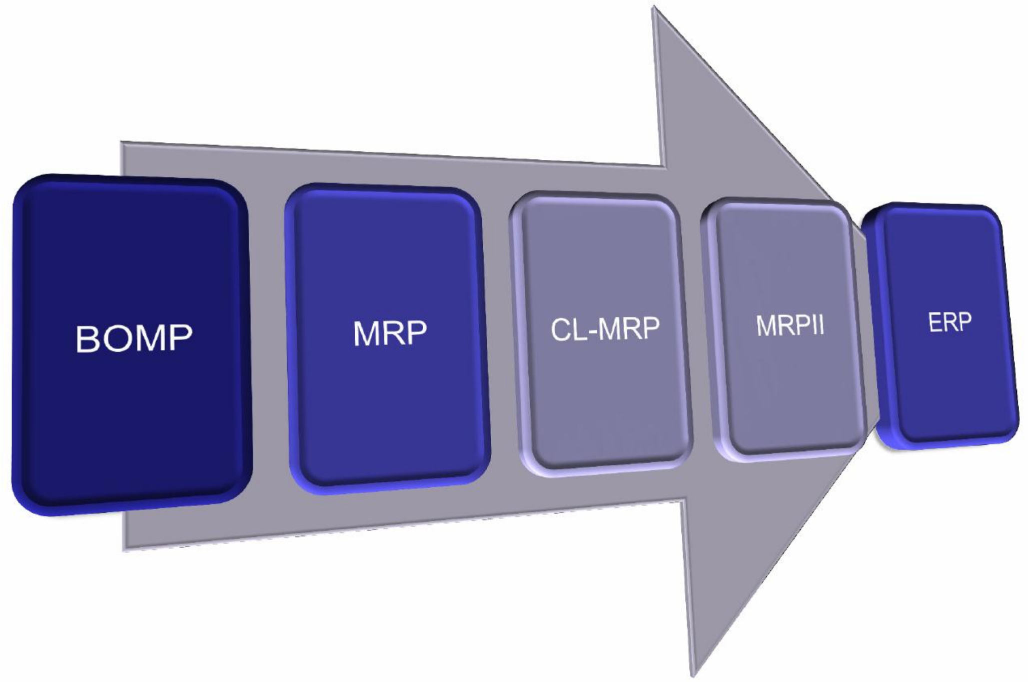


Figure 2: Historical development of ERP systems (Alfnes, 2011)

Bill of material processor (BOMP) which came before the MRP, was a tool able to compute component requirements for a product based on its bill of materials (BOM). Gradually in 1960s – 1970s BOMP, combined with ICS (inventory control systems), was developed into material requirements planning systems (MRP) (Moller, 2005) which, in addition to the previous functions, were considering stock levels and production lead times in the calculations. However, the MRPs did not take account for the machines' capacity which could result in unrealistic plans and ultimately in inability to deliver customer orders on schedule, thus reducing customer satisfaction. Closed-loop MRP (CL-MRP) filled up this gap. The next step of the advancement of enterprise systems (ES) was manufacturing resource planning (MRP II) systems which were developed in 1970s – 1980s to include among others sales, production and cash flow control functions (Sadler, 2007). The term enterprise resource planning (ERP) was first coined in 1990 by the Gartner Group (work of Wylie (1990) mentioned by Jacobs and Weston Jr (2007)). As it is described in the introduction to this chapter, ERPs are meant to integrate the internal value chain of an enterprise (Moller, 2005) in this way enhancing its core functions by gaining more overview and control over the enterprise's internal processes, with MRP still being the basic functionality of the software. A typical structure of an ERP system is shown at Figure 3.

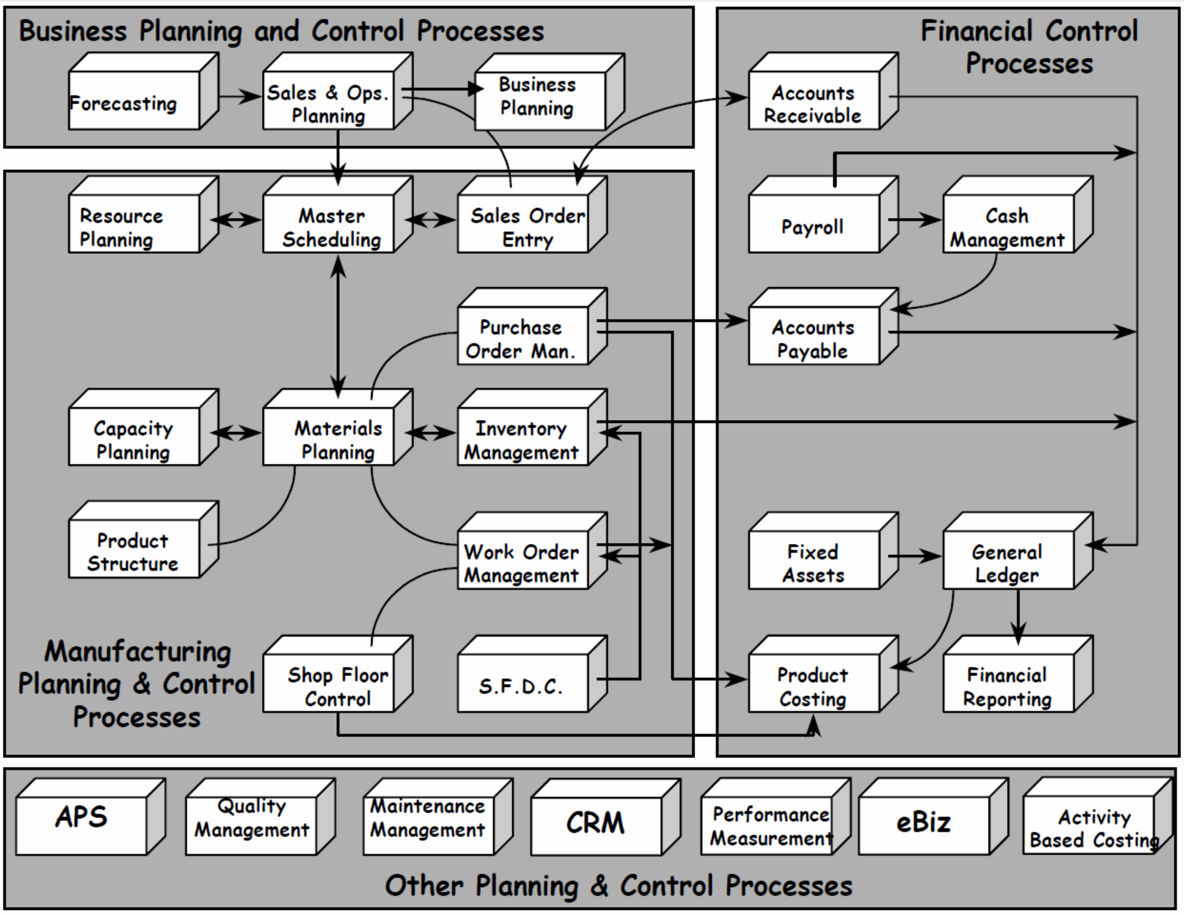


Figure 3: Generic structure of a typical ERP system (Bititci, 2003)

We see that original ERP concept as well as the ERP's definition is mostly about the internal processes of an organization. This concept however contrasts to nowadays focus and research (Akkermans et al., 2003, Williamson et al., 2004, Moller, 2005, Pearlson and Saunders, 2009, Chopra and Meindl, 2010, Harrison et al., 2004) pointed to managing entire supply chain with an enterprise being just a part of it, thus we can see the need of a broader perspective also when considering an ERP system.

3.1.2 ERPs in Supply Chain Management Perspective

According to Mentzer et al. (2001) supply chain management is defined as "*the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole*".

The perspective of supply chain management (SCM) enforces collaboration and integration requirements on the enterprise, thus enforcing the same requirements on its enterprise system. Such a broader perspective, according to a large number of sources (Frohlich and Westbrook, 2002, McCarthy and Golicic, 2002, Cagliano et al., 2003, Harrison et al., 2004, Simatupang and Sridharan, 2004, Williamson et al., 2004, Chopra and Meindl, 2010) and the definition itself, promises a variety of advantages, e.g. less stock, reduced bullwhip effect (bullwhip effect is shortly explained in *Appendix C: Bullwhip Effect*), shorter lead times and generally increased operational performance. But how good are the current ERP systems at meeting these requirements?

3.1.2.1 *Original ERP Concept and the SCM Perspective*

Akkermans et al. (2003) and his Delphi study, where 23 European supply chain experts where participating (Delphi technique is shortly described in section *3.2.2.1.1*), discovered top 12 key issues in the field of supply chain management (SCM), with the top 6 of them, voted on by 35 and more per cent of the experts participating in the survey, presented below:

1. Further integration of activities between suppliers and customers across the entire chain.
2. How to maintain flexibility in ERP systems to deal with changing supply chain needs?
3. Mass customization: complex assortments, shorter cycle times, less inventory.
4. Who will be in the driver's seat in supply chain co-ordination?
5. Supply chains consisting of several enterprises.
6. Full exchange of information with all the players in the chain.

Observing that four (1, 4, 5 and 6) of the six issues above are about supply chain collaboration, integration and information sharing, we can clearly see a trend in the SCM field.

Further, the ERP's contribution to these twelve top SCM issues was studied in the same work. It was found that the enterprise resource planning systems seemed to positively influence only 4 of the top 12 SCM issues, namely:

1. More customization of products and services.
2. More standardized processes and information.
3. The need for worldwide IT systems.
4. Greater transparency of the marketplace.

Even more, we can see that only one of these 4 positive contributions, the contribution to products' customization, is among the top 6 issues presented above. Furthermore, only 2 (number 2 and 3) of the four are *indirectly* supporting the clear trend of extended cooperation across the enterprises borders, observed above.

This reasoning clearly illustrates the weaknesses of the original ERP concept for the modern supply chain perspective, especially when it comes to the trend of collaboration between and integration of the different enterprises in the chain. And indeed, Akkermans et al. (2003) claims that ERP systems can even limit the progress in the field of SCM, naming 4 major limitations:

1. Their insufficient extended enterprise functionality in crossing organizational boundaries.
2. Their inflexibility to ever-changing supply chain needs.
3. Their lack of functionality beyond managing transactions.
4. Their closed and non-modular system architecture.

The first limitation is, not surprisingly, about the ERP systems' lack of supply chain-wide collaboration and integration functionality. But how important is this limitation, or, say it in other words, how much gain is there for a supply chain when an extensive collaboration and integration is enabled between the supply chain's enterprises?

As it is mentioned introductorily in this section, a number of studies have been conducted to reveal these gains, some of the works saying specifically that the tighter integration (which is impossible without collaboration) between the organizations in a supply chain is, the more visible benefits that supply chain can obtain (Frohlich and Westbrook, 2002, Cagliano et al., 2003, Harrison et al., 2004, Simatupang and

Sridharan, 2004). E.g. Harrison et al. (2004) describes 4 escalating dimensions of integration and provides expected benefits for each of the dimensions, see Table 1.

Dimension	*Elements*	*Benefits*
Information Integration	▪ Information sharing & transparency ▪ Direct & real-time accessibility	▪ Reduced bullwhip effect ▪ Early problem detection ▪ Faster response ▪ Trust building
Synchronized Planning	▪ Collaborative planning, forecasting & replenishment ▪ Joint design	▪ Reduced bullwhip effect ▪ Lower cost ▪ Optimized capacity utilization ▪ Improved service
Workflow Coordination	▪ Coordinated production planning & operations, procurement, order processing, engineering change & design ▪ Integrated, automated business processes	▪ Efficiency & accuracy gains ▪ Fast response ▪ Improved service ▪ Earlier time to market ▪ Expanded network
New Business Models	▪ Virtual resources ▪ Logistics restructuring ▪ Mass customization ▪ New services ▪ Click-and-mortar models	▪ Better asset utilization ▪ Higher efficiency ▪ Penetrate new markets ▪ Create new products

Table 1: Supply chain integration dimensions (Harrison et al., 2004)

In addition to dimension names and benefits, the table above also provides a list of necessary elements that must be in place, for each dimension, and therefore its benefits, to be achieved. According to Harrison et al. (2004), *information integration* here refers to sharing information between members of the supply chain while *synchronized planning* is the joint design and execution of plans for product introduction, forecasting and replenishment, also what is to be done with the shared information. Bearing the focus of this thesis in mind, namely demand planning and forecasting, the first two degrees of integration seem to be of particular interest for us, especially the element "collaborative planning, forecasting and replenishment" (CPFR) which is required in second dimension. Let us now have a closer look at it with the purpose of finding out what CPFR can teach us about the current state of the art demand planning process.

3.1.2.2 CPFR

Collaboration planning, forecasting and replenishment has emerged as a response to the SCM perspective and, according to Attaran and Attaran (2007), can be seen as the final stage in the evolution of supply chain collaboration. The evolution process itself is illustrated in Table 2. It is worth noticing that the first stage of this evolution, electronic data interchange (EDI), corresponds with the elements in the first dimension of supply chain integration from Table 1.

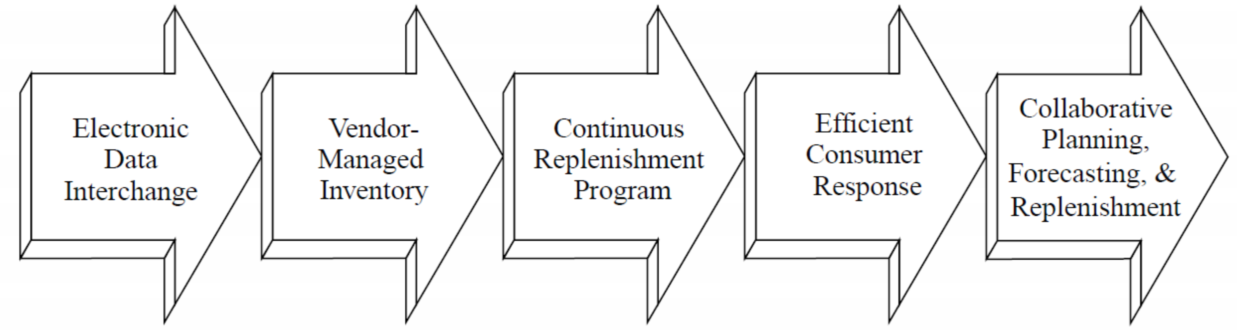


Table 2: Evolution of supply chain solutions (Attaran and Attaran, 2007)

Different sources (McCarthy and Golicic, 2002, Fliedner, 2003, Attaran and Attaran, 2007) provide slightly different description of a CPFR process, varying at the number of steps and their names, but all agree, either implicitly or explicitly, that the CPFR process is an iterative one. The essence of the process can be described in the following way:

1. *Collaborative agreement*: Create a partnership agreement to specify among other objectives, metrics and requirements of the collaboration.
2. *Joint planning*: Jointly create a plan of meeting the objectives, align relevant business processes.
3. *Joint forecasting*: Create and share forecasts with intention to reach an agreement on one common forecast for all the partners involved.
4. *Collaborative forecast's exceptions handling*: Resolve the exception/disagreements of the partners' forecasts. One common forecast is created.
5. *Creating and filling the orders*: Using the common forecast, generate the orders and replenish inventories.
6. *Analysis and reviewing*: Analyze and review the process in order to come up with modifications and improvements on any step of the process.

A well-established CPFR process is believed to provide advantages even if only one manufacturer and retailer are involved, i.e. it does not require a critical mass of participating vendors and customers to pay off (Attaran and Attaran, 2007). The potential advantages CPFR provides are supposed to be on both the manufacturer's and the retailer's side, in addition to the shared supply chain benefits (Fliedner, 2003).

3.1.2.3 Modern Approach to ERP Systems

It is shortly described in *3.1.2.1 Original ERP Concept and the SCM Perspective* how Akkermans et al. (2003) has discovered that ERP systems were able to provide only a limited support to supply chain management. The concept of ERP II, elaborated by Moller (2005), can be viewed as a response to the discovered limitations of ERP systems. The concept of ERP II, as the term ERP, was originally perceived by Gartner Group (Bond et al., 2004), which defined ERP II as *"… a business strategy and a set of industry-domain-specific applications that build customer and shareholder value by enabling and optimizing* *enterprise and inter-enterprise, collaborative-operational and financial processes"*. As we can see from the definition, the scope of the system is now extended to support inter-enterprise collaboration. Moller (2005) proposes a conceptual framework of ERP II which is illustrated at Figure 4.

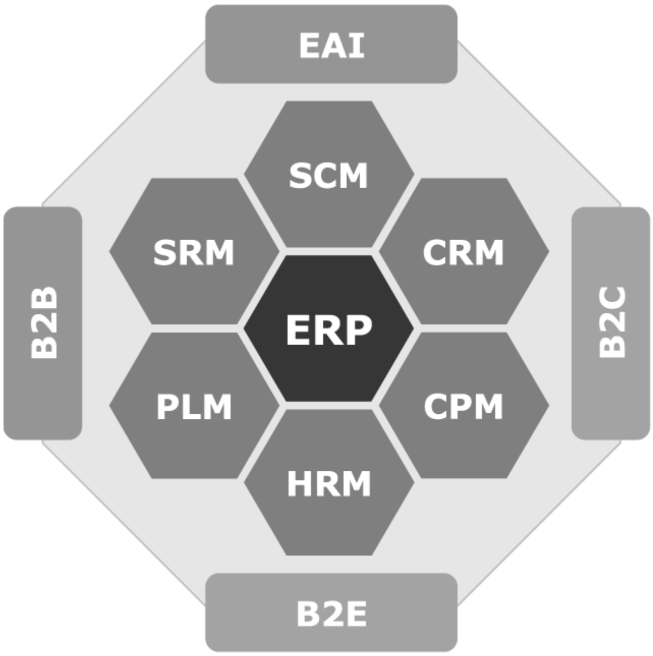


Figure 4: The conceptual framework of ERP II (Moller, 2005)

As we can see from the figure, the proposed structure for ERP II is modular and layer-based, i.e. each layer consisting of different modules. The framework is further explained at Table 3.

Layer	Components	
Foundation	Core	Integrated database (DB) Application framework (AF)
Process	Central	Enterprise resource planning (ERP) Business process management (BPM)
Analytical	Corporate	Supply chain management (SCM) Customer relationship management (CRM) Supplier relationship management (SRM) Product lifecycle management (PLM) Employee lifecycle management (ELM) Corporate performance management (CPM)
Portal	Collaborative	Business-to-consumer (B2C) Business-to-business (B2B) Business-to-employee (B2E) Enterprise application integration (EAI)

Table 3: The four layers of ERP II (Moller, 2005)

Classical ERP system and its core components stand as the basis other modules be built upon. These modules, firstly, include the tools to provide decision support in corporate and relations issues and, secondly, include collaborative components dealing with cooperation and integration with external actors. In this way, the idea of ERP II is supposed to extend the original ERP concept in the aspects of flexibility, increased functionality and, as expected, collaboration and integration aspects. In this way ERP II is aiming at eliminating the ERP systems' limitations discovered by Akkermans et al. (2003) and described in section *3.1.2.1 Original ERP Concept and the SCM Perspective*.

Moller (2005) concludes his work with remarks about the ERP II-concept currently being implemented in modern ERP solutions. Looking into the future of ERP systems, we can clearly see a trend of moving towards web-enabled solutions based on ERP II-philosophy and, as Jacobs and Weston Jr (2007) suggest, systems utilizing artificial intelligence and simulation to assist decision-making. What if the future is already here?

3.1.3 Microsoft Dynamics AX 2012

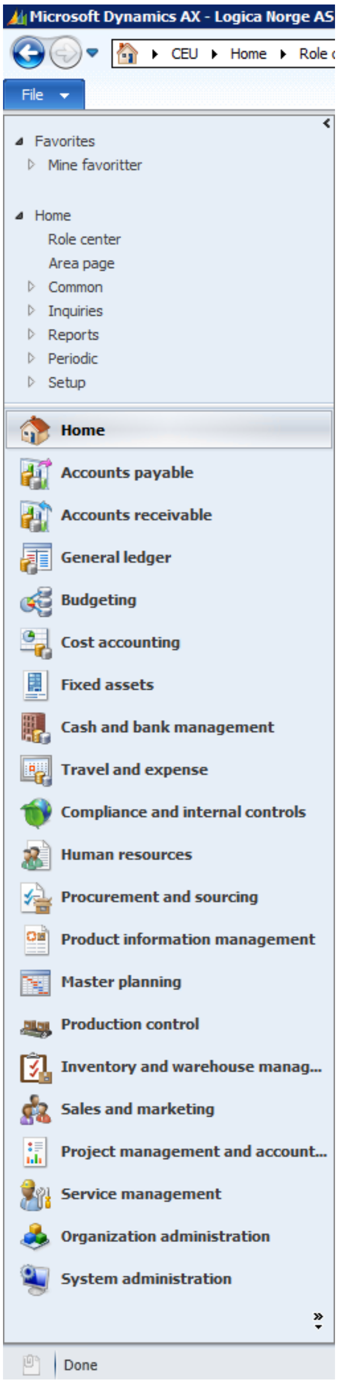


Figure 5: Navigation pane in Microsoft Dynamics AX

One of the many ERP systems available today is Microsoft Dynamics AX, which is formerly known as Axapta. The first version was released in 1998 by Danish company Damgaard, which was then merged with Navision (also Danish), and finally Navision-Damgaard was acquired by Microsoft in 2002 and Axapta was renamed to Dynamics AX. Description given in this section applies to Microsoft Dynamics AX 2012 – the most current version available at present moment.

3.1.3.1 General Description

Navigation pane of Dynamics AX 2012 is presented at Figure 5 showing the modules available in the system. First and obvious thing to mention here is that the system is modular so that not all modules are needed for the system to function and the ERP's functionality can relatively easy be extended with new modules (if they exist) in case a company using it decides so. The potential functionality does not only include purchase, sales, production and other order and transaction management, but also has such modules as *Human resources*, *Project management and accounting*, functions for customer relationship management, CRM, (built-in in the *Sales and marketing* module) and so on. According to Microsoft (2012b) and FindTheBest (2012), AX 2012 also possesses support for supply chain management and business intelligence (BI).

The ERP system uses so-called "layering" to separate and control the updates and modifications made in the application to make sure that any user can customize AX 2012 to suit his or her needs and that the standard application is never overwritten by the customizations. This is a concept that ensures that modifications will never interfere with application objects on lower and more fundamental levels (Microsoft, 2006). The eight Dynamics AX' layers are presented at Table 4. The three lower layers are used by the ERP system itself while the five upper layers, in theory, can be modified by developers and end users. If we want to implement e.g. the Demand Planning Module not as a third party module, similarly with the discontinued Demand Planner from TXT, but rather internally in Dynamics AX, it will be developed on the four outer layers using AX' MorphX development platform and X++, the language the application is written in. It is an object-oriented language with similarities to C# and integrated SQL queries (Microsoft, 2011). This thesis however will not go into the technical details specific to Microsoft Dynamics AX 2012 development and will rather focus on requirements specification and user-oriented design of demand planning functionality.

Layer	Description
USR	The user layer is for user modifications, such as reports.
CUS	The customer layer is for modifications that are specific to a company.
VAR	Value Added Resellers (VAR) can make modifications or new developments to the VAR layer as specified by the customers or as a strategy of creating an industry specific solution.
ISV	When an Independent Software Vendor (ISV) creates their own solution, their modifications are saved in the ISV layer.
SLN	The solution layer is used by distributors to implement vertical partner solutions.
FPK	The FPK layer is an application object patch layer reserved by Microsoft for future patching or other updates.
GLS	When the application is modified to match country or region specific legal demands, these modifications are saved in the GLS layer.
SYS	The standard application is implemented at the lowest level, the SYS layer. The application objects in the standard application can never be deleted.

Table 4: Layers in Microsoft Dynamics AX 2012 (Microsoft, 2012a)

Microsoft Dynamics AX 2012 integration capabilities are also claimed to be considerable. Application Integration Framework (AIF) provides a capability to integrate Microsoft Dynamics AX 2012 with other systems inside and outside an organization by enabling the exchange of data through XML (Arias, 2012). Having in mind that extensible markup language (XML) is currently the most common tool for data transmission between all sorts of applications (W3Schools, 2012), we can see that the Dynamics AX aims at providing integration opportunities with almost any internal or external system.

All in all, Microsoft Dynamics AX 2012 shows a clear trend at moving towards the ERP II vision: Layers and modularity, extended functionality and decision support, as well as its integration capabilities. It looks like Moller (2005) was right concluding his work with the final remark: "ERP II is dead - long live ERP!"

3.1.3.2 Demand Planning and Forecasting Functionality

The general aspects of Microsoft Dynamics AX 2012 are considered above, but which opportunities does the ERP system have for demand planning? In general, we see that most of the modules of a typical ERP system (compare Figure 5 to Figure 3) present at Dynamics AX 2012, but not the demand planning or forecasting module which this thesis is especially concerned with, as it is described in *Introduction*. At least the module is not shown explicitly in the modules list. As it is e.g. with CRM functionality, the demand planning and forecasting functions are built-in in another modules – *Inventory and warehouse management* and partly in *Master planning*.

Forecasting functionality found in *Inventory and warehouse management* module is illustrated at Figure 6.

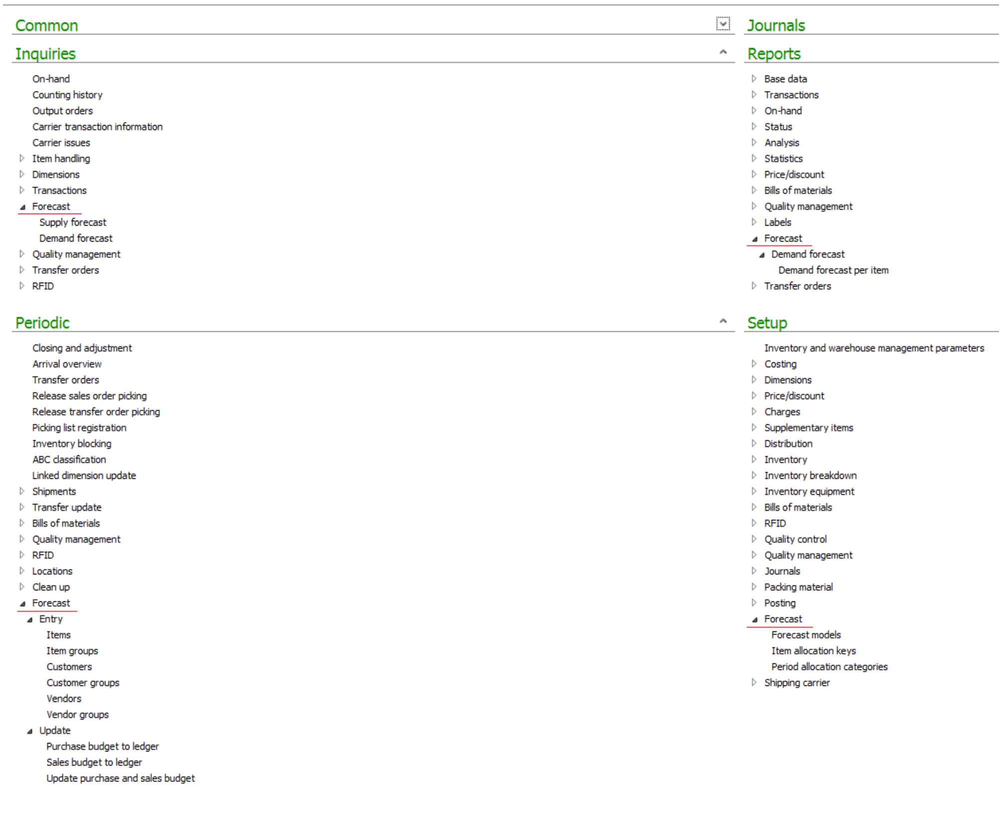


Figure 6: Forecasting options at Inventory and warehouse management module

The forecast planning process in Microsoft Dynamics AX 2012 is based on individual items with independent demand. It is possible to enter, but not to generate, supply and demand forecasts and the inventory forecast is then generated automatically based on the entered forecast values. When entering a forecast, first thing to do is to create or choose a forecast model. These models are used to identify and structure predictions for e.g. different time periods, product families or geographical regions. Each model can have one level of disaggregation: It is possible to attach several submodels to a model, but submodels cannot have their own submodels. The forecast values themselves can be inserted and viewed for items, item groups, customers, customer groups, vendors and vendor groups. One can insert a forecast line manually, using the method *Period*, i.e. plan for the same amount of items each specified period of time and a specified planning horizon or using the method *Key*, i.e. a pre-specified percentage demand distribution per period for a chosen forecasting horizon and period length. Period keys, to use in *Key*-method can be defined at *Setup – Forecast – Period allocation categories*. Functions *Inquiries – Supply/Demand forecast* show current forecasts item by item and *Reports – Forecast* is able to generate a forecasting report and print it to chosen media (e.g. screen, printer, file, e-mail etc.).

Module *Master planning* and its function *Forecast scheduling* offers integration of the entered forecasts into the planning activities of the ERP system.

We have now shortly uncovered what AX 2012 can offer when it comes to demand planning, but is it good enough? Or, say it in other words, what is the current state of the art demand planning process?

3.2 Demand Planning

In order to develop a requirements specification for Demand Planning Module there is a need to understand the demand planning as a process and to get an overview of different forecasting methods available.

First of all, we must eliminate possible confusion; the terms *demand planning* and *demand forecasting* must be clarified. According to Oxford Dictionaries (2011) the word "forecast" means *"predict or estimate (a future event or trend)"*, which, applied to the term "demand", means predicting or estimating future demand. The term "demand planning" is defined as *"the process of forecasting future customer demand"* in Kilger and Wagner (2008). It looks like that in practice the terms' meaning is the same, even though it is sometimes considered that demand planning is a more broad term (SCDigest, 2009), the two expressions will be used interchangeably in this work.

Demand planning is much more than just using a random forecasting method to predict customer demand and there are developed a number of forecasting/demand planning frameworks, considering which we can fully see how extensive demand planning can be. There are three such frameworks studied here, they will be presented and briefly described further down, then a "common framework", which is an attempt to combine the three into one more general framework, will be proposed and properly described.

Kilger and Wagner (2008) present the framework illustrated at Figure 7. It is the most extensive framework among the tree considered in this thesis, and it shows how a process of demand planning should be organized.

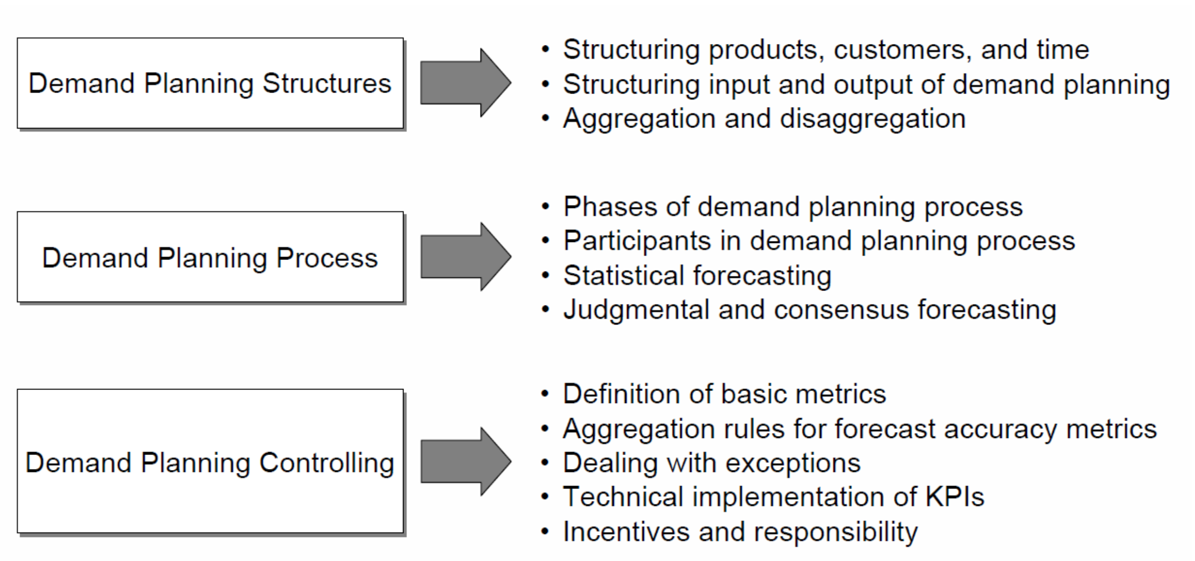


Figure 7: Demand planning framework presented by Kilger and Wagner (2008)

The figure illustrates that the demand planning is separated into three steps, each with a number of corresponding substeps. The authors then illustrate further division of step number two (Demand Planning Process) by presenting 6 substeps of it as shown at Figure 8.

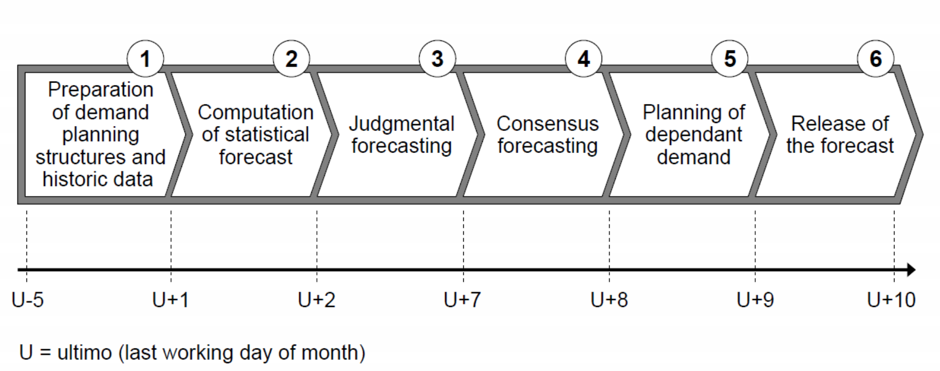


Figure 8: Phases of a demand planning process presented by Kilger and Wagner (2008)

Let us now shortly describe the three major steps in this framework:

- *Demand Planning Structures*: This step is the preparatory one. Both the input and the desired output data must be structured in a way that supports the forecast process and the processes which rely on the forecast.
- *Demand Planning Process*: In this step the forecasting process itself takes place. The data prepared at the previous step is fine-tuned and used to create actual forecast by using both statistical and judgmental methods (more on different methods can be found in section *3.2.2 Forecasting Methods*). The goal here is come up with one-number/consensus forecast which is the common forecast for all parties involved.
- *Demand Planning Controlling*: The last step aims at reviewing and improving the forecast and demand planning process generally. It is necessary to assure that the forecast is reliable and therefore is trusted and used by the stakeholders.

The next framework considered in this work, is a forecasting framework called "Basic approach to demand forecasting", presented in Chopra and Meindl (2010). This one consists of 6 steps and focuses on how to establish effective forecasting process in an organization seen in supply chain management perspective:

1. *Understand the objective of forecasting*: Identify the decisions which are based on the forecast and are therefore dependent on it.
2. *Integrate the demand planning and forecasting throughout the supply chain*: All the decisions identified in the previous step must be integrated into the forecasting process, e.g. all the stakeholders should participate in the creation of the forecast.
3. *Understand and identify customer segments*: Customer segments must be identified and grouped. Often companies may use different forecasting methods for different user groups.
4. *Identify major factors that influence demand forecast*: Prior to the forecast generation, all major factors affecting the forecast must be identified. One may e.g. be interested in finding out demand patterns, deciding products which demand must be forecasted especially accurately, discovering substitutional products etc.
5. *Determine the appropriate forecasting technique*: The name is self-explaining. Note: Different user groups and products may require different forecasting methods (more on different forecasting techniques can be found in section *3.2.2 Forecasting Methods*)

6. *Establish performance and error measures for the forecast*: Clear performance measures must be established to measure the forecasting result and these measures should be aligned with the goals of decisions which are dependent on the forecast.

The third and last forecasting framework considered here, has the same aim as "Basic approach to demand forecasting", but lacks the supply chain orientation. It is illustrated beneath (Figure 9).

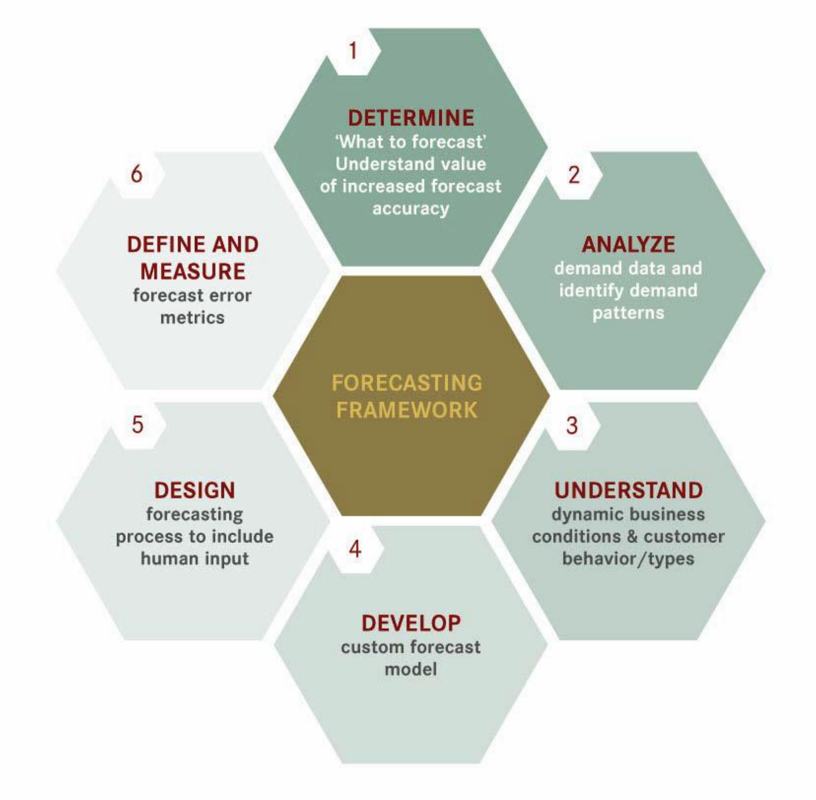


Figure 9: Forecasting framework presented by Global Supply Chain Laboratory (n.d.)

This framework, like the previous one, consists of 6 steps and all of them are briefly explained on the figure. It is worth noticing that the two latter frameworks are very similar in essence, but the last one focuses on a custom forecasting model and, similarly to the first framework, aims to add human judgment while the second one suggests usage of already established forecasting techniques saying nothing about combining human and statistical forecasts.

The focus of the three frameworks mentioned above is somewhat different: The first one describes an already established effective process of demand planning, while the two latter ones takes a perspective of assisting an organization with establishing of such a forecasting process. Their essence is also not exactly the same, though one can see many similar points in all the three and a "common framework" seems to be of interest.

3.2.1 Proposed Common Framework

A detailed framework for demand planning is described in this section. As mentioned previously, the common framework is a combination of three other frameworks and, what is more important, a combination of their approaches and perspectives. The work of Kilger and Wagner (2008), being the most extensive of the three, is used as a basis while the two others are used as extensions to it, as well as a number of other sources are used to clarify or support some of the important points. Another source of inspiration for the common framework is the CPFR process elaborated at section *3.1.2.2 CPFR*. Analyzing the three frameworks above and comparing the results to the CPFR process, one can see many similar elements and, considering the potential value a well-established CPFR process can provide, it is reasonable to believe that the common framework will only benefit from including CFPR framework as one of its bases. All the four frameworks were analyzed, compared and merged into one presented below. The result is believed to reflect the current state of the art demand planning process for an enterprise seen in a supply chain management perspective with all the challenges and possible benefits this perspective provide. The proposed framework itself is presented at Table 5.

Common demand planning framework	
1. <u>Demand Planning Awareness</u>	
1.1	Understand the objectives of forecasting
1.2	Understand major relevant business conditions
2. <u>Demand Planning Structures</u>	
2.1	Determine what to forecast
2.2	Structure products, customers, regions and time
2.3	Structure input and output
2.4	Aggregation, disaggregation and consistency
3. <u>Demand Planning Process</u>	
3.1	Collect, correct and analyze input data
3.2	Determine appropriate forecasting techniques
3.3	Quantitative forecasting
3.4	Add human judgment
3.5	Collaborative forecasting
3.6	Plan dependent demand
3.7	Release the forecast
4. <u>Demand Planning Controlling</u>	
4.1	Define and measure forecast error metrics
4.2	Aggregation rules for forecast accuracy metrics
4.3	Deal with forecasts errors and biases
4.4	KPIs and responsibility with incentives
4.5	Reevaluate the process

Table 5: Proposed common demand planning framework

3.2.1.1 Demand Planning Awareness

Before performing the forecasting itself, there is a need to understand the forecast implications on the company and have some organizational issues in place.

3.2.1.1.1 Understand the objectives of forecasting

Many decisions and planning activities in a supply chain can be based upon forecasts or be influenced by the forecasts. First of all it is necessary to detect all of those decisions/planning activities as well as those who are responsible for making/performing them. All parties affected by a forecast should be aware of this link and this link should exist at the information system level. Creation of a cross-functional or even cross-organizational team may be required for this step. Completing this step will also provide insight in exactly what value increased forecast accuracy may bring to each stakeholder so that the concrete objectives of the demand planning process can be set.

3.2.1.1.2 Understand major relevant business conditions

Major business conditions relevant for a forecasting process can be on demand, supply or product side.

On the demand side it is essential to bear in mind the difference between sales and actual demand (SCDigest, 2009, Challa and Shukla, 2010, Chopra and Meindl, 2010). Demand can be said to be equal sales when no "artificial" factors (like promotions or discounts, unmet demand because of stockouts etc.) are present. It is not less important to focus on meeting the ultimate customer demand (Harrison et al., 2004, Attaran and Attaran, 2007, 2009), i.e. the actual demand of the end user of the product in order to counter the bullwhip effect (see *Appendix C: Bullwhip Effect*). On the supply side the presence of substituting suppliers and suppliers' lead times must be considered in order to find out the desired forecast accuracy. And on the product side there is a need to identify if there are any products which demand is correlated (e.g. they are substituting each other), in case there are, there should be run a joint forecast for these products (Chopra and Meindl, 2010).

3.2.1.2 Demand Planning Structures

Current step deals primarily with the data required in demand planning process.

3.2.1.2.1 Determine what to forecast

After finding out which organizational or inter-organizational functions are affected by the forecast, it should be possible to find out exactly what needs to be forecasted. Besides, asking the question "What to forecast?" can lead us to the data (read correct time-series) we need in order to make required forecasts. Also here it is important to identify the dependent demand (i.e. parts of other products) which a company does not want to forecast since it can be computed using the forecast of independent demand and BOM (Chopra and Meindl, 2010).

3.2.1.2.2 Structure products, regions and time

Both Kilger and Wagner (2008) and Chopra and Meindl (2010) agree that each forecast has three dimensions, but they disagree at what these dimensions are. The first work suggests product, geographical region and time, while the second one names customers instead of geographical area. These two can be said to actually constitute one dimension, as it will be clear from the example in point 2.4 below (section 3.2.1.2.4). Each of the dimensions should be segmented, i.e. geographical regions (with corresponding customers), product groups and time buckets along which to run the forecast, should be identified.

Wagner, in his previous work at the same field (Wagner, 2005), mentions that a three-dimensional database's size can increase very fast even for mid-sized companies, which may implicate performance issues on a software module using it. Still even in 2005, as it seems from his work, the issue was solvable by the technology available then, so we have a reason to believe that there will be no problem with the database's size using modern technology.

3.2.1.2.3 Structure input and output

Having points 2.1 and 2.2 (sections 3.2.1.2.1 and 3.2.1.2.2) of the framework in place, it is possible to find exactly what input data are required to run the desired forecasts and what output they should produce.

3.2.1.2.4 Aggregation, disaggregation and consistency

The dimensions' segmentation, mentioned in point 2.2 (section 3.2.1.2.2), should be done in a way that supports aggregation and disaggregation of forecast data, i.e. the segmentation should have several hierarchical levels. An example of hierarchical segmentation may be:

- *Geography*: Global – Area – Country – Region – City – Customer
- *Product*: All products – Group – Subgroup – Product
- *Time*: Year – Quarter – Month – Week – Day

Aggregation to higher levels happens by simple summation. Disaggregation to lower levels is more problematic and can occur according to one of the following rules:

- *Even distribution*: Higher level items are distributed evenly to the lower level groups.
- *Existing quantities on lower level*: If lower level groups do already contain some item quantities, their distribution ratio is calculated, and the newly entered higher level items are distributed according to that ratio.
- *Some other time-series*: Higher level items are distributed according to some other time-series/ratio, e.g. the one calculated from previous year demand for the same period.

Having this level-approach allows future forecast to fit different purposes, e.g. it can be suitable for both financial planning (one year planning horizon) and operational planning (one day planning horizon, e.g. how many items of this type to produce today). However planners at different levels may want to enter data of various level of aggregation which can imply data consistency issues. Kilger and Wagner (2008) propose two different ways to solve those issues:

- *Immediate propagation of changes*, i.e. all changes are aggregated to the higher levels and disaggregated to the lower levels automatically applying pre-defined aggregation and disaggregation rules showing conflicts at once. This can make altering of forecast data very slow.
- *Consistency checks*, i.e. aggregation and disaggregation, is triggered manually, followed by the system applying consistency checks on the data and reporting any exceptions that have to be solved manually, e.g. by collaborating or by having a hierarchical forecast responsibility in place when one party is able to overrule the other party's decisions.

It looks like immediate propagation of changes is preferable since it enforces user to reconsider the data he or she is entering, or to take this decision in collaboration with others (see 3.2.1.3.5), so that there is no way an inconsistency is undiscovered until someone chooses to manually activate consistency checking. Performance issues are expected to be insignificant with modern technology.

3.2.1.3 Demand Planning Process

The actual process of applying forecasting techniques is described in this step.

3.2.1.3.1 Collect, correct and analyze input data

In case not all data needed for forecasting are available, they have to be collected. The link on the information system level from point 1.1 (section 3.2.1.1.1) is of big importance here. Corrections of historical data may also be required, e.g. in case of promotions, for distinguishing between the sales and the actual demand, as it is described in point 1.2 (section 3.2.1.1.2) of the framework. Further, the data have to be analyzed for determining e.g. demand patterns. If done manually, a graphical presentation of data is of great interest.

3.2.1.3.2 Determine appropriate forecasting techniques

Next substep is to make a decision on what/which forecasting method(s) to use. Sometimes forecasting software can offer a pick-the-best or best-fit option, i.e. automatic method selection and parameter estimation function which helps to automate the process of choosing a forecasting model. It is important to notice that different dimensions and various segments in a dimension may require different forecasting techniques. For instance products or product groups can be further grouped using ABC inventory classification (more thoroughly explained in *Appendix D: ABC Inventory Classification*): A few A-class items standing for the most part of the annual usage (unit cost multiplied by unit usage), several B-class items standing for considerable annual usage and many C-class items standing for low usage (Arnold et al., 2008). Having this classification, it is reasonable not to spend too many resources on forecasting C-class items' demand and rather focus on A and B items.

3.2.1.3.3 Quantitative forecasting

The applying of the chosen quantitative/statistical methods occurs at this point. Different quantitative forecasting techniques are explained in section 3.2.2.2 *Quantitative Methods*. In an extensive collaboration environment (read supply chain perspective), simple forecasting techniques are often used due to potentially vast numbers of items and frequent forecasts (Fliedner, 2003). Note, that not all forecasts will be able to utilize these methods since they require sufficient amount and quality of historical data (time-series). In addition, the qualitative forecasting techniques are often better suited for long-term forecasting so that statistical forecasting may be intentionally left behind in some cases. More on this can be found in section *3.2.2 Forecasting Methods*.

3.2.1.3.4 Add human judgment

The next move is to combine statistical and subjective perspectives. It is described in 3.2.2.1 *Qualitative Methods* that many authors from the literature reviewed in this thesis consider combining qualitative and quantitative techniques to have a great potential for increasing forecast accuracy. However, Kilger and Wagner (2008) specify that human corrections are desired only in case they are based on the information which is not considered by the statistical methods used, else the same information is accounted for twice, which means increased forecast error.

In some cases, as said in the previous substep, quantitative techniques cannot be applied and some forecasts need to use qualitative ones to come up with a value at all.

3.2.1.3.5 Collaborative forecasting

After the previous two substeps are done, it is essential that the goal of one number forecasting is reached (Kilger and Wagner, 2008, SCDigest, 2009, Chopra and Meindl, 2010), i.e. all the stakeholders identified at substep 1.1 (3.2.1.1.1) have been able to agree on a common or joint forecast so that a consensus on the forecast values is reached and all exceptions and disagreements are solved. At this point, all the exceptions due to inconsistency of manually entered or altered forecasts are automatically identified by the mechanism of immediate propagation of changes (3.2.1.2.4). This can be done by arranging a consensus meeting, which can be all from same time same place meeting to ICT-supported different time different place meeting. In case not all exceptions are solved, the next move will be creating a hierarchy of forecasting where one party can overrule other party's predictions, e.g. based on its weighting factor (described further below). Each party taking part in the consensus decision, should contribute to the final forecast, but its contribution weight (weighting factor) is dependent on the forecast accuracy improvements the party has achieved by making judgmental corrections in the past. In order to enable this, there should be a mechanism of tracing the human-made corrections to their source as well as measuring the corrections' "value" (as described below in substep 4.4, section 3.2.1.4.4). The existence of a mechanism that provides feedback to human adjustments in itself is increasing the adjustments' accuracy (Chopra and Meindl, 2010).

3.2.1.3.6 Plan dependent demand

The estimated demand for the products which there were not created forecast for due to limitations mentioned in point 2.1 (3.2.1.2.1), can now be computed based on the consensus forecast and BOMs.

3.2.1.3.7 Release the forecast

The forecast including all the products is released, and other planning activities which are dependent on the forecast, identified in point 1.1 (3.2.1.1.1), can now start or be corrected based on the latest information.

3.2.1.4 Demand Planning Controlling

The last step of the common framework (Table 5) is about controlling and improving the current demand planning process.

3.2.1.4.1 Define and measure forecast error metrics

No decision makers would base their decision on a forecast which quality and accuracy are uncertain. To check the forecast's quality and provide an opportunity to improve the forecasting process, some forecast error metrics should be defined and measured. Those metrics are extensively described in the section 3.2.3 *Forecasting Error*.

3.2.1.4.2 Aggregation rules for forecast accuracy metrics

As the forecast data should be able to aggregate and disaggregate (point 2.4, section 3.2.1.2.4) so should the accuracy metrics. When viewing the forecast values at a certain level of aggregation, one should be able to find the forecast accuracy of exactly the same level. Thus, forecast accuracy calculation should be run along the same dimensions as the forecast itself.

3.2.1.4.3 Deal with forecast errors and biases

In case forecast error calculation shows that a forecast is biased, i.e. it is consistently over- or under-forecasting the demand, as explained in section 3.2.3 *Forecasting Error*, changing the forecasting method should be considered.

Likewise with point 3.1 (3.2.1.3.1), it may be valuable to evaluate forecasting accuracy graphically, e.g. as it is illustrated at Figure 10.

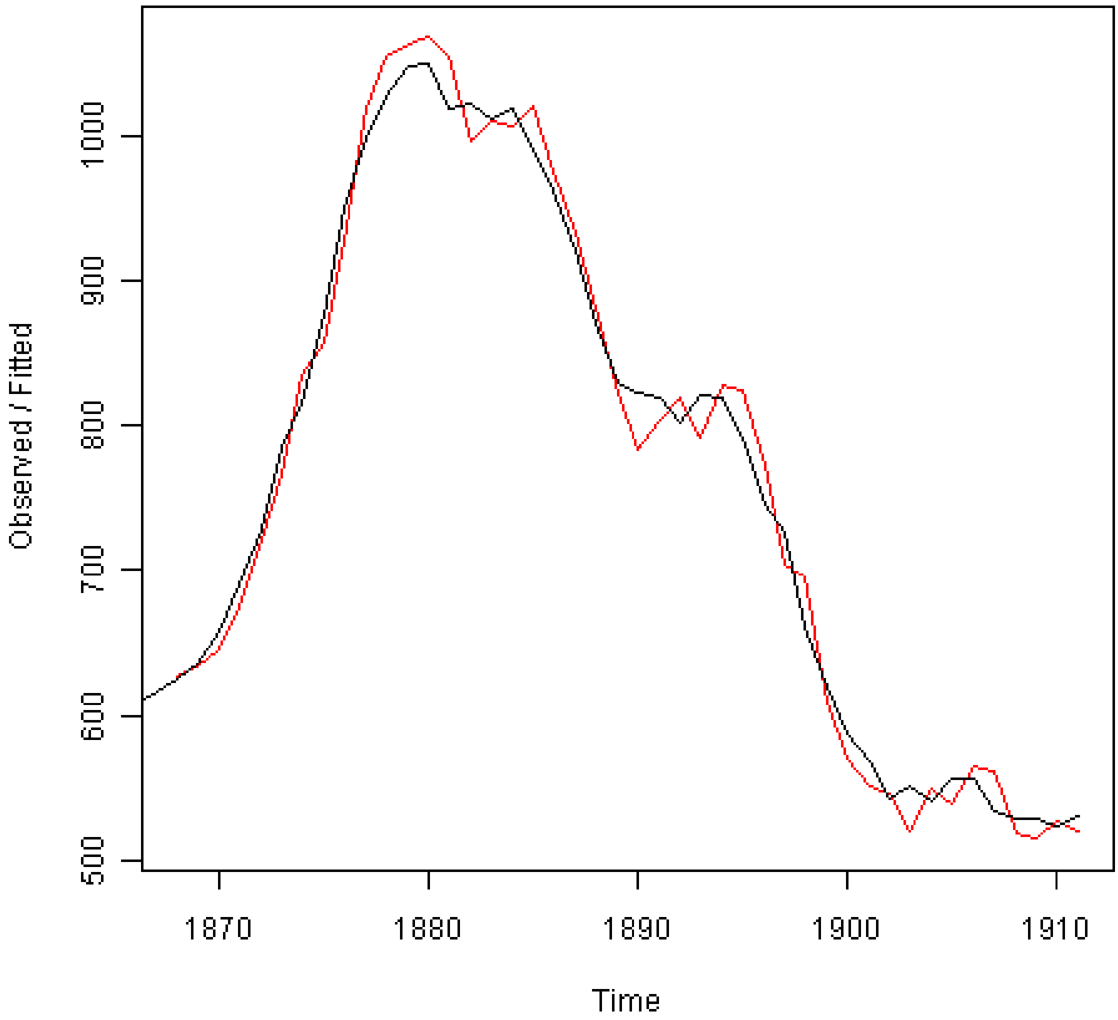


Figure 10: Graphical illustration of forecast accuracy (Coghlan, 2010)

3.2.1.4.4 KPIs and responsibility with incentives

One can use mean absolute percentage accuracy (MAPA), described in section 3.2.3 *Forecasting Error*, to measure if a contribution to a forecast actually adds value, i.e. measure FVA (forecast value added). If e.g. judgmental corrections are made to an automatically generated quantitative forecast, after the actual demand observations are made and MAPA-values are calculated, it is possible to subtract MAPA of the forecast before the correction from the MAPA of the corrected forecast to see if the value was added by the correction. If the result of the subtraction is positive, then the correction was valuable. Having this mechanism in place it is possible to find out the contribution of each human correction and assign targets and incentives for the contributors as well as to estimate the relative weight of their judgments under a consensus meeting or their place in the hierarchical structure of forecast corrections.

3.2.1.4.5 Reevaluate the process

Finally, the whole process should be reviewed, analyzed and possibly improved. Implementing such a complicated collaborative process across organizational boundaries is anything else than easy, and it will most certainly be room for improvement after the process is first established. This last substep ensures these improvements are identified and merged into the demand planning process.

That is the last point of the proposed common demand planning framework which contains many links to the section *Forecasting Methods* coming right beneath.

3.2.2 Forecasting Methods

There are developed a large variety of methods for forecasting demand, but to use any of them properly one needs some basic understanding of the nature of demand forecasting itself. That is: forecasts are always wrong and their error increases as it is forecasted further into the future, further down the aggregation level or further upstream in the supply chain (Chopra and Meindl, 2010). The points about forecast accuracy decreasing with time distance and granularity level are also supported by Kilger and Wagner (2008). We have that any demand pattern has a systematic and a random component that should not be interfused. The objective of any forecasting method is to predict the systematic component and to estimate the random component's size and variation, which is the measure of forecast error.

Literature reviewed under this thesis contains many methods for forecasting demand (its systematic component, to be exact) and the methods' classification varies from one source of information to another. For the purpose of convenience and clarity a general classification, which largely corresponds with the literature and will be used further in this work, is presented here. For instance Chopra and Meindl (2010) suggests there are four main types of forecasting methods: Qualitative, time-series, causal methods and simulation, while e.g. Fildes (1979), Archer (1980) and Efendigil et al. (2008) divide the methods into two more general categories: qualitative and quantitative (or numerical) methods. The latter classification is used in this thesis since the term quantitative method can be applied to both time-series, causal methods and simulation. See Table 6 for illustration of the proposed classification. There exist many different forecasting techniques, but since this thesis does not aim to deliver a complete description of as many forecasting methods as possible, only some of them, the most referred to in the relevant literature, are shown at Table 6 and will be shortly described in this section. In-depth description of complex mathematical algorithms behind some of the methods is omitted.

Forecasting methods classification			
Qualitative			
	The Delphi technique		
Quantitative			
	Naïve		
	Time-series		
		Static	
		Adaptive	
			Moving average
			Simple exponential smoothing
			Holt's model
			Winter's model
			Box-Jenkins' method
	Causal		
	Simulation		

Table 6: Proposed forecasting methods classification

Qualitative (also called judgmental or subjective) methods are the ones that are primarily subjective and rely on informed human judgment (Archer, 1980, Chopra and Meindl, 2010). Both Archer (1980) and Chopra and Meindl (2010) claims that such techniques are often used when the quality or quantity of historical data is not sufficient, when experts have information which is not represented by historical demand or to make long-term forecasts.

The term *"quantitative* (also called numerical or statistical) methods" in the literature often denotes time-series or causal methods which will be explained further in this section. Naïve techniques, which can be considered a very simplified version of time-series, can also be grouped into this category as well as the simulation, using which, according to Chopra and Meindl (2010), it is possible to combine time-series and causal methods. This group of methods relies on historical data and is usually more appropriate for short- or mid-term forecasts.

3.2.2.1 Qualitative Methods

This thesis is ultimately focused on a software module thus, apparently, it may seem most appropriate to pay attention to quantitative techniques, which a computer is able to utilize in a very efficient manner, and to leave discussion of the qualitative methods behind. This point of view may seem reasonable, but much of the literature insists that human judgment, combined with quantitative methods, may increase forecast accuracy considerably (Archer, 1980, Mathews and Diamantopoulos, 1986, Pereira et al., 1989, Flides et al., 2006, SCDigest, 2008, Kilger and Wagner, 2008, Chopra and Meindl, 2010), and it is therefore decided not to let them behind even when considering a software tool. One, often used and often referred to, qualitative method is presented below to illustrate the judgmental approach to demand forecasting.

3.2.2.1.1 The Delphi technique

The most referred qualitative method in the literature is the Delphi technique; it is therefore the one chosen to illustrate this group of methods. The point of Delphi technique is to reach a consensus of a panel of experts that never directly communicate with each other (Archer, 1980). All the communication happens via the directing staff. The experts answer a series of questions and send the answers back to the staff which then summarizes results. The next round consists of informing the experts about the group results and giving them an opportunity to correct their predictions. Continuing in this way, ideally, leads towards a convergence of the panel's opinion as the final result.

3.2.2.2 Quantitative Methods

Naïve methods, time-series, causal methods and simulation is described in this section.

3.2.2.2.1 Naïve methods

Naïve methods are the simplest among the quantitative forecasting techniques. Estimating the demand for the future period to be equal the demand of the previous period is the most mentioned naïve method in the literature. Other similar techniques can be estimating future period demand to be equal the demand of the corresponding previous period (Hippert et al., 2004), e.g. this summer demand equals previous summer demand, or to be equal previous period demand multiplied by a growths rate (Martin and Witt, 1989), which is also called trend. These methods are considered to be the "cheapest" and are often used as a starting point which the results of other more "expensive" forecasting technique can be compared to (Kilger and Wagner, 2008).

3.2.2.2.2 Time-series

Time-series methods (also called extrapolating methods) are the ones that use historical demand data to generate forecast for future demand. The demand's systematic component is considered to consist of level, trend and seasonality and can be modeled in several ways, the so-called *mixed form* (Chopra and Meindl, 2010) will be used as an example in this work:

*Systematic component = (level + trend) * seasonality*

According to Chopra and Meindl (2010), time-series forecasting methods can be static or adaptive. To lighten the theory part of this thesis, it is decided not to provide more extensive description of time-series here. Instead, the description with respective formulas and figures can be found in *Appendix B: Static and adaptive Time-series*.

3.2.2.2.2.1 Box-Jenkins' method

The method of Box and Jenkins is often referred to in the literature and it provides a nice transition to the causal methods and will therefore be described here as the last method time-series technique. This method is sometimes considered to be at least one of the most sophisticated techniques for analyzing time series data (Archer, 1980). It utilizes a complex mathematical algorithm, including the autoregressive and moving-average models, ARMA (autoregressive moving-average), sometimes also adding an "integrated" term to become ARIMA (autoregressive integrated moving-average), to find the best match of a time-series to its historical values so that it is possible to extrapolate these values into the future, i.e. make a forecast. On a more advanced level Box-Jenkins is also able to utilize other time-series which are thought to be correlated to the one the forecaster is interested in. Archer (1980) mentions a work of Wandner and Van Erden (1979) where it is shown, on an example of forecasting tourism demand, that at a high level of sophistication Box-Jenkins becomes causal in its approach and can be used as a more affordable alternative to building econometric models, i.e. causal forecasting.

3.2.2.2.3 Causal forecasting

Causal methods are also called cause-and-effect or econometric methods. Such techniques are based on the assumption that the data that needs to be forecasted is strongly correlated with other factors, for example it is obvious that demand on most of the products is affected by supply and the current economic situation (read customers' income level). Causal forecasting is usually done by means of regression analysis. An econometric model can take into account one or more factors which are considered to influence the variable to be forecasted, they are called independent variables while the one being forecasted is a dependent variable. In a causal forecasting a hypothesis of type presented right below is formulated:

$$D = f(A, B, C)$$

The equation above is an example merely for illustration purpose. It states that demand *D* is a function of independent factors *A*, *B* and *C*, which are more than one, meaning this is a multivariable regression. The simplest form of such a model is linear, i.e.:

$$D = a + bA + cB + dC + e$$

The regression's goal is to find such values of the coefficients *a*, *b*, *c* and *d* so that the error term *e* is minimized.

Archer (1980) states that in practice it is unlikely that the dependent variables will have such a simple relation to the dependent one. It is more likely for the relation to be multiplicative, i.e.:

$$D = a \cdot A^b \cdot B^c \cdot C^d \cdot e$$

The equation can then be linearized using the logarithms:

$$\log D = \log a + b \log A + c \log B + d \log C + \log e$$

After running the regression and identifying the coefficient values, the expected values of the independent variables are fed into the model to get a demand forecast. This literally means that the coefficient values are assumed to be constant, which is justifiable only during a certain period. Archer (1980) estimates this period to be two years, and if the forecast is needed more than two years ahead, a detailed investigation with aid of the experts is said to be necessary.

It is clear that developing and using an econometric model is more expensive in terms of both forecasters' time and computing resources compared to e.g. time-series, and therefore there should be clear reasons for doing so instead of using time-series methods. One could for example expect increased accuracy of forecasts when preferring a causal method, but this expectation contradicts with the claims of Makridakis (1986), mentioned in the work of Martin and Witt (1989), as well as with their own results supporting Makridakis' statement, which is: *"Econometric models are not necessarily more accurate than time series (extrapolative) models"*. Martin and Witt (1989) see the main advantage of causal forecasting in opportunity to perform what-if analysis since the variables influencing the demand are already included into the model and can be altered to see the effect of change of certain factors directly on the demand values. Similar findings are also presented by Geriner and Ord (1991).

3.2.2.2.4 Simulation

Simulation here can be described as imitation of consumers' behavior in order to predict their decisions regarding demand for a certain product. This method is seldom mentioned in the literature as a forecasting technique, but its usability for what-if analysis is mentioned (Kilger and Wagner, 2008, Chopra and Meindl, 2010) as well as it is stated that this function is very important for a demand planning software (Chopra and Meindl, 2010): Simulating the effects of promotions, sales, campaigns, advertisements etc., is able to assist decision-making process in demand planning. Comparing this information to the material provided in the end of the precious section, *Causal forecasting*, we can draw a conclusion that causal methods can be used as simulation techniques.

3.2.3 Forecasting Error

Being successful at predicting the systematic component of demand is not the same as developing a successful demand forecast since the demand has also a random component, which still remains to be estimated. According to Chopra and Meindl (2010) one is interested in estimating the random component's size and variability, not its direction (positive or negative), since, ideally, sum of the components for a number of periods is supposed to be zero. Having a non-zero sum means that the forecasting method applied is over- or underestimating the demand and probably needs to be revised.

In a forecast, the random component appears in form of a forecast error so that, usually, a suitable forecasting technique has an error which size is comparable to the random component's size (Chopra and Meindl, 2010). A forecast error (e_t) is the difference between forecasted (F_t) and actual demand (D_t):

$$e_t = F_t - D_t$$

There are developed a number of error measurements for analyzing and getting valuable information out of the errors.

Firstly, size and variation of the forecast error is important to know for many of decision-makers within organization as many decisions can depend on this information, for instance safety stock level. Some of the metrics of error's size and variation often met in the literature (Geriner and Ord, 1991, Blocher et al., 2004, Kilger and Wagner, 2008, Chopra and Meindl, 2010), are described below:

1. *Mean squared error* $$MSE_n = \frac{\sum_{t=1}^{n} e_t^2}{n}$$

   According to Chopra and Meindl (2010) MSE is related to error's variance and it is estimated that the random component of demand has a mean equal to 0 and variance equal to *MSE*.

2. *Mean absolute deviation* $$MAD_n = \frac{\sum_{t=1}^{n} |e_t|}{n}$$

   Blocher et al. (2004) and Chopra and Meindl (2010) state that *MAD* can be used to estimate random component's standard deviation (σ): $\sigma = 1.25 \cdot MAD$

3. *Mean absolute percentage error* $$MAPE_n = \frac{\sum_{t=1}^{n} \left|\frac{e_t}{D_t}\right| \cdot 100\%}{n}$$

   Compared to the absolute metrics above, *MAPE* is a relative metric and is often used for describing forecast error as a percentage of demand.

   Instead of measuring forecast error one can focus on calculating forecast accuracy:

4. *Mean absolute percentage accuracy* $$MAPA_n = \frac{\sum_{t=1}^{n} APA_t}{n} \cdot 100\%$$

Where APA_t is:

5. *Absolute percentage accuracy* $$APA_t = \max\{100\% - APE_t ; 0\}$$

With APE_t is given by:

6. *Absolute percentage error* $$APE_t = \frac{|e_t|}{D_t} \cdot 100\%$$

Secondly, as described in the beginning of this section, it is of interest to find out if the forecast is consistently over- or underestimating the demand, i.e. if it is biased:

$$Bias_n = \sum_{t=1}^{n} e_t$$

Bias greater than zero means that the forecast is overestimating demand while negative bias demonstrates underestimation of demand.

Another way to detect over- or underforecasting is by using tracking signal (TS):

$$TS_t = \frac{Bias_t}{MAD_t}$$

Blocher et al. (2004) and Chopra and Meindl (2010) suggest to use ±6 as the extreme values for tracking signal, that is $TS > +6$ means serious overforecasting while $TS < -6$ is a sign of serious underforecasting. In both cases using of new forecasting method should be considered.

3.3 Literature Findings

This chapter is divided into three parts. The *first* one provides a short description of ERP systems in general: Their evolvement from 1950s to nowadays, typical functionality and their relation to the current attempt to see an enterprise in a bigger picture of supply chain management (SCM). It was identified that for a few years ago ERP systems could not provide much support to SCM and could actually limit the progress at that field. As a response to this, a concept of ERP II was developed, aiming at eliminating the classic ERP limitations for SCM and providing the ERP systems mechanisms to support inter-organizational integration and collaboration with all the benefits it delivers. Then a generic description of Microsoft Dynamics AX 2012 is offered together with a short elaboration of the extent to which the systems complies with the ERP II vision. The conclusion is that AX 2012 clearly moves towards that vision, it appears like Microsoft is anything else than unconscious about the current trends in the ERP and SCM fields. Lastly, the central part of Microsoft AX' demand planning functionality is shortly described.

The *second* part first and foremost offers a framework, which can be used to structure a demand planning process, an overview of some of the different forecasting methods available and most common error metrics developed to measure the error which is always present in every forecast.

The proposed common demand planning framework (Table 5), is developed by studying, analyzing and thereafter combining three other frameworks and a discovered collaborative planning, forecasting and replenishment process (CPFR) into one structure, which is mainly taken from the most extensive of the three demand planning frameworks. The steps of the other two had to be reordered and reevaluated to fit into the common structure and, of course, a number of other sources was used to further extend and support the work. Then it was discovered, that CPFR had much in common with the combined framework and even more, it was able to bring the elements, and therefore benefits, of SCM view into the demand planning process which the proposed framework describes. At the end, we have the common demand planning framework being a derivative of four other methods and consisting of four major steps:

1. *Demand Planning Awareness*: Understanding the purpose, benefits and conditions of demand planning process.
2. *Demand Planning Structures*: Structuring data in a way that allows "best practice" demand planning process.
3. *Demand Planning Process*: The process itself, including qualitative, quantitative and collaborative forecasting.
4. *Demand Planning Controlling*: Reviewing and analyzing the forecast's results and possibly improving the process based on the discovered findings.

If we now go back to the functionality for demand planning and forecasting AX 2012 possesses, and compare it with the findings above, we will see that this functionality is simply deficient: No opportunity whatsoever to generate a forecast automatically, underprovided functionality for displaying the forecast data along different dimensions and aggregation levels, no generation of forecast error report etc. This topic is uncovered in more detail at chapter *5 Demand Planning Module Requirements Specification*.

This is the *third* and final part of the chapter which aim is, firstly, to draw some conclusive lines, secondly, to evaluate the literature study's quality and propose a way to further improve it, and, thirdly, to explain the choices done performing the study.

The central remark regarding the choices done in the literature study is the one about the placement of common framework at the theory part of the chapter. According to classic report structure it is common to place summarizing frameworks at the end of the literature review chapter as the chapter's summary. The common framework presented here, however, is not a summary of literature findings, but a finding itself.

Conclusive lines about the findings are attempted to be drawn above, and it remains to evaluate the literature study' quality and propose a way to further increase its value. The quality can be assessed by elaborating if the research questions from 1.2 *Problem Statement and Scope* were answered. In this case, only the first question is primarily aiming at the literature study, and it is supposed to be fully answered by the common demand planning framework presented and described at 0

Proposed Common Framework and summarized here. The solution to research question number two is the *Demand Planning Module Requirements Specification* presented at the first section of chapter 5. Strictly, the literature study does not answer it directly, but rather indirectly since the results in chapter 5 are enabled by this literature study. Research question three is answered in the last section of chapter 5 and in chapter 7, which, in turn, is based on the results from the fifth chapter.

Artificial intelligence and simulation were briefly mentioned in this chapter, but there is generally little attention paid to these topics in the literature study; one way to improve the study's quality is to incorporate research of the above-mentioned topics into it. Another, and probably more prioritized improvement suggestion, is to further work on the proposed common demand planning framework in order to make it more clear and understandable so that it is able to provide as obvious as possible process description for any enterprise to follow.

Based first and foremost on the common framework, requirements specification for Demand Planning Module is developed in chapter *5 Demand Planning Module Requirements Specification*. The next chapter (4) presents a description of the process of gathering these requirements.

4 Developing Software Requirements

During the literature study, while gaining more understanding of the field of demand planning, a list of requirements for a Demand Planning Module began to arise. Analysis of the sources led to insights about what kind of functionality is needed for the module, which were written down as the study progressed. At the end of the theory review the "preliminary" requirements list, that was considered complete, and the literature findings were cross-checked against each other to ensure that no requirements are left behind or are unsupported by the theory. Proposed common demand planning framework, being the theoretical apogee of this thesis, is the main source of inspiration for requirements specification provided in the next chapter.

The design of the general requirements specification table (Table 7), aiming at being applicable for any IT system with forecasting and demand planning functionality, is adopted from the materials kindly provided by this thesis' supervisor Odd Jøran Sagegg from Logica. These materials have been modified to suit the thesis, e.g. the column *Fit/gap* and other columns irrelevant for the purpose of the table were omitted. More about the table and its columns' meaning is explained in section *5.1 General Functional and Non-functional Requirements*.

After the general requirements specification table was finished, the requirements provided in it and the AX 2012 functionality, partly uncovered in section *3.1.3 Microsoft Dynamics AX 2012*, were compared and analyzed in order to find out in which extent AX is able to support these requirements. Table 8 presents the results of this analysis. Its structure reminds the structure of Table 7 because the same materials provided by Odd Jøran Sagegg were used as the basis for the table's design, but this time the number and the names of the columns were modified: Columns *Fit/gap* and *Priority* were added. More about the table and its columns' meaning is explained in section *5.2 Microsoft Dynamics AX 2012 Specific Requirements Specification*.

5 Demand Planning Module Requirements Specification

This chapter has two sections both containing requirements specification tables for a demand planning module. First section contains a table with general requirements specification, while the second one is the result of analyzing the general requirements and their fit for Microsoft Dynamics AX 2012.

5.1 General Functional and Non-functional Requirements

Based on the literature study, the table of general requirements specification was developed and it is presented below (Table 7). These requirements are supposed to be general, i.e. suitable for any demand planning software independently of its vendor and developer.

#	*Requirement*	*Comments/explanation*	*Source*
	Functional requirements		
FU	*Users grouping*		
FU-1	Different user groups	Different permissions and functionality for different user groups.	3.2.1.3.5
FU-2	User groups hierarchy	Different capabilities to overrule other's forecasts based on organizational hierarchy and/or dynamic weighting factors (see FF-13).	3.2.1.3.5
FD	*Data analysis*		
FD-1	Graphical presentation of historical demand data	Visualization of data to assist manual demand pattern recognition.	3.2.1.3.1
FD-2	Classification of products	ABC classification of products. Products with dependent and independent demand.	3.2.1.3.2 and 3.2.1.3.6
FD-3	Segmentation of products	All products – Group – Subgroup – Product	3.2.1.2.2
FD-4	Segmentation of geographical regions	Global – Area – Country – Region – City – Customer	3.2.1.2.2
FD-5	Segmentation of time periods	Year – Quarter – Month – Week – Day	3.2.1.2.2
FD-6	Aggregation and disaggregation along all 3 dimensions	Required for FF-3.	3.2.1.2.4
FF	*Forecasting, error reporting and human involvement*		
FF-1	Several basic quantitative forecasting methods and algorithms available	Naïve, time-series.	3.2.1.3.3, 3.2.2.2.1 and 3.2.2.2.2
FF-2	Quantitative advanced forecasting algorithms available	Causal.	3.2.1.3.3 and 3.2.2.2.3

FF-3	Error measures and calculation of forecast error	Allows seeing how effective forecasting in this case is. Critical for improving forecast accuracy. Required for FF-4, 7, 8, 9 and 15.	3.2.1.2.4
FF-4	Forecasting and displaying forecasts' values and errors along all 3 dimensions at different aggregation levels	System's usefulness for different planning levels.	3.2.1.2.4
FF-5	Opportunity to use different forecasting methods for different product and market groups and for different time buckets	More customized and therefore more accurate forecasts fitting for different planning levels	3.2.1.2.4
FF-6	Computation of dependent demand	Based on independent demand forecast and BOM.	3.2.1.3.6
FF-7	Generate forecast error report	Based on forecast error metrics and actual observed demand when available.	3.2.1.4.1
FF-8	Highlighting forecasts with tracking signal greater than 6 or lower than -6	Pointing attention to biased forecasts.	3.2.1.4.1 and 3.2.3
FF-9	Graphical presentation of forecasting error data on the same plot as actual observed demand data	Allows seeing the forecasting accuracy graphically.	3.2.1.4.3
FF-10	Best-fit function	Automatic suggestion of best-fit forecasting method for a given historical time-series based on the calculated forecast error.	3.2.1.3.2
FF-11	What-if analysis/simulation	Assist planning of campaigns and promotions. Requires FF-2, since causal methods can be used for what-if analysis.	3.2.2.2.3
FF-12	Human correction of statistical forecasts	Correct the statistically computed forecast values.	3.2.1.3.4
FF-13	Human insertion of forecasts	Directly type in anticipated forecast values when no computed value available.	3.2.1.3.4
FF-14	Traceability of all the human corrections and insertions	Required for FF-17.	3.2.1.3.5
FF-15	Ability to store different forecast values for the same item when forecasts come from different sources	So that it can be agreed on a joint value afterwards. Until a joint value is agreed upon, the forecast made by the party with highest permission level/weighting factor is considered the main value.	3.2.1.3.5
FF-16	Overview screen showing different forecast values entered by different parties with the functionality to edit these values or choose the final value if appropriate permissions are granted to the viewer	Support for collaborative forecasting.	3.2.1.3.5

FF-17	Weighting factor calculation based on FVA	Calculation of FVA of each human correction and assigning respective weighting factor to that user/user group.	3.2.1.4.4
FF-18	Immediate propagation of changes	Run aggregation and disaggregation (and therefore consistency checks) of entered forecast values and report conflicts immediately after insertion.	3.2.1.2.4
	Non-functional requirements		
NI	*Interoperability and integration*		
NI-1	Import and export of Excel files	Interoperability with other software.	Common sense
NI-2	Integration capabilities with other software via internet	Critical for cross-organizational integration and collaboration.	3.1.2

Table 7: General requirements specification

Table explanation:

- Column "#" stands for unique number of the requirement. The number is decided in the following way:
  - First letter, F or N, stands for "functional" or "non-functional".
  - Second letter is the same as first letter in the name of this group of the requirements.
  - Number is the number of the current requirement in this group, from 1 to X, where X is a natural number.
  - Example: FF-13 stands for "Functional requirement in the group *Forecasting, error reporting and human involvement* number 13".
- Column "Requirement" stands for the requirement name, often self-explaining.
- Column "Comments/Explanation", not surprisingly, has as its goal to explain or further elaborate on the given requirement.
- Column "Source" provides a cross-reference to the section(s) in the theory study where this particular requirement is mainly taken from.

5.2 Microsoft Dynamics AX 2012 Specific Requirements Specification

Based on the general requirements specification from the previous section and the analysis of AX and its functionality, especially forecasting functionality, shortly uncovered in section *3.1.3 Microsoft Dynamics AX 2012*, AX 2012 specific requirements specification is presented in Table 8 below. Its aim is to show the extent to which standard AX 2012 is able (or unable) to support the current state of the art demand planning process identified in the literature study.

Even before having a look at the table below, just by comparing the Table 7 above and the description of AX 2012 functionality from *3.1.3 Microsoft Dynamics AX 2012*, it seems reasonable to believe that many gaps in standard AX 2012 will be identified. Insufficient Microsoft Dynamics AX 2012 demand planning support is, after all, the main motivation for this thesis. Let us now study the results of the comparison.

#	Requirement	Fit/gap	Priority
	Functional requirements		
FU	*Users grouping*		
FU-1	Different user groups	Fit	High
FU-2	User groups hierarchy	Gap	Medium
FD	*Data analysis*		
FD-1	Graphical presentation of historical demand data	Gap	Medium
FD-2	Classification of products	Fit	Medium
FD-3	Segmentation of products	Fit-gap	High
FD-4	Segmentation of geographical regions	Fit-gap	High
FD-5	Segmentation of time periods	Fit-gap	High
FD-6	Aggregation and disaggregation along all 3 dimensions	Gap	Medium
FF	*Forecasting, error reporting and human involvement*		
FF-1	Several basic quantitative forecasting methods and algorithms available	Gap	Medium
FF-2	Quantitative advanced forecasting algorithms available	Gap	Low
FF-3	Error measures and calculation of forecast error	Gap	High
FF-4	Forecasting and displaying forecasts' values and errors along all 3 dimensions at different aggregation levels	Gap	Medium
FF-5	Opportunity to use different forecasting methods for different product and market groups and for different time buckets	Gap	Medium
FF-6	Computation of dependent demand	Fit	High
FF-7	Generate forecast error report	Gap	High
FF-8	Highlighting forecasts with tracking signal greater than 6 or lower than -6	Gap	Medium
FF-9	Graphical presentation of forecasting error data on the same plot as actual observed demand data	Gap	Medium
FF-10	Best-fit function	Gap	Low
FF-11	What-if analysis/simulation	Gap	Low
FF-12	Human correction of statistical forecasts	Gap	Medium
FF-13	Human insertion of forecasts	Fit	High
FF-14	Traceability of all the human corrections and insertions	Gap	Medium

FF-15	Ability to store different forecast values for the same item when forecasts come from different sources	Gap	Medium
FF-16	Overview screen showing different forecast values entered by different parties with the functionality to edit these values or choose the final value if appropriate permissions are granted to the viewer	Gap	Medium
FF-17	Weighting factor calculation based on FVA	Gap	Medium
FF-18	Immediate propagation of changes	Fit	High
	Non-functional requirements		
NI	*Interoperability*		
NI-1	Import and export of Excel files	Fit	High
NI-2	Integration capabilities with other software via internet	Fit	Medium

Table 8: AX 2012 specific requirements specification

Table explanation:

- Columns "#" and "Requirement" are the same as in Table 7.
- Column "Fit/gap" can have three values:
  - "Fit", meaning that the current requirement is supported in AX 2012 by standard.
  - "Gap", meaning the requirement is unsupported or supported to low extent by standard AX 2012 so that customization is needed.
  - "Fit-gap", meaning the requirement is supported, but not to a full extent by standard AX 2012 so that some customization is needed
- Column "Priority" indicates the importance of the given requirement for a demand planning process.
  - Value "High" means that the given requirement is crucial for running a demand planning process at all.
  - Value "Medium" means that the given requirement represents more advanced functionality and is necessary for running a nearly "best practice" demand planning process.
  - Value "Low" means that the given requirement represents advanced functionality and should be implemented in order to provide extended functionality and decision support to the user of the system.

Elaborating the table, one can see that the expectation of many gaps in standard AX 2012 at the field of demand planning was confirmed. However, not surprisingly, it is found possible to run a demand planning process in standard AX 2012: Most of the high priority rated requirements are supported by default. Running the "best practice" process, the way it was identified in the literature study, is, nevertheless, impossible. This observation strengthens the thesis' motivation and encourages continuing the work on finding a way to implement the support for the current state of the art demand planning process in Microsoft Dynamics AX 2012. Following the logical thread from *Introduction*, which reasons for the usefulness of demand planning functionality build inside the ERP system, and not as a third party extension, the technical design of Demand Planning Module is omitted since all the functionality are to be a part of AX 2012 and its design. Succeeding chapters present the process of developing user-oriented solution design, the design itself and associated functional modification specifications.

6 Developing User-oriented Solution Design

Following the line started at chapter 4, this thesis continues its effort to be as close as possible to the Logica's documentation standards and processes when it comes to software development. The following chapter, as the foregoing one, uses materials provided by Odd Jøran Sagegg. This time it is the materials illustrating how a user-oriented solution design and functional modification specifications should be build up and a short presentation of the development processes Logica uses. There are two such processes: *Microsoft Dynamics Sure Step Methodology* and *FremDrift*. According to my supervisor from Logica, the first one is not currently being used to a full extent, in addition, the methodology is very extensive. It appears more appropriate to use *FremDrift*, especially when taking into account that the provided examples of user-oriented solution design are built using the latter methodology. Major phases in *FremDrift* are illustrated at Figure 11.

Figure 11: Major phases in FremDrift (Søndergaard, 2006), translated from Norwegian

This thesis concentrates about the analysis phase which is further divided into 7 subphases illustrated at Figure 12.

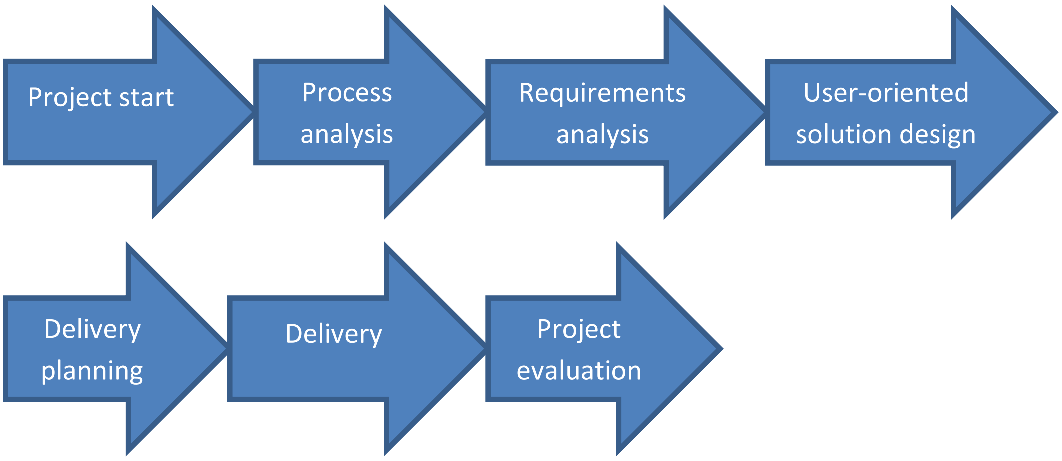


Figure 12: Subphases in analysis phase in FremDrift (Søndergaard, 2006), translated from Norwegian

As we can see, subphases 2 – 4 are relevant for this work. *Literature Study* can be places in subphase *Process analysis*. In "real life" it would mean analyzing business processes in an organization, but for the purpose of this work, *Process analysis* subphase literally means studying the descriptions of "best practice" demand planning process in the literature. Chapter 5 fits under *Requirement analysis* subphase and the next chapter, *User-oriented Solution Design*, is obviously the subphase 4 of the analysis phase of *FremDrift*. Let us move straight to it.

7 User-oriented Solution Design

Results from previous research (both in the literature and in the requirements chapters) have shown that Microsoft Dynamics AX 2012 possesses significant opportunities for integration with other applications. Due to this fact and the explanations in the section *1.2 Problem Statement and Scope* about holding AX-wide integration issues out of scope, only functional requirements from Table 8 are considered here. The table shows which of the requirements revealed under the theory study are supported by Dynamics AX by default and which of them need AX 2012 to be customized. The requirements are also ranged from high to low priority.

Usually, a consulting company with its well-trained professionals is to develop such documents. It may be too much of a work to fully develop a solution design with all the corresponding functional modification specifications for one student with no extensive training in AX 2012. It is therefore decided to concentrate on high priority requirements, successful solving of which will result in a somewhat improved demand planning process compared to the standard Dynamics AX forecasting procedure.

7.1 Base Solution

This section describes solutions to almost all functional high-priority and some medium-priority requirements. These requirements are:

1. Different user groups (FU-1)
2. Segmentation of products (FD-3)
3. Segmentation of geographical regions (FD-4)
4. Segmentation of time periods (FD-5)
5. (Partly) Several basic quantitative forecasting methods and algorithms available (FF-1)
6. Error measures and calculation of forecast error (FF-3)
7. Generate forecast error report (FF-7)
8. Highlighting forecasts with tracking signal greater than 6 or lower than -6 (FF-8)
9. Human insertion of forecasts (FF-13)
10. Immediate propagation of changes (FF-18)

7.1.1 Log on

Requirement: FU-1 (Standard).

Log on to AX 2012 as usual and be automatically assigned permissions corresponding to your user group.

7.1.2 Segmentation of product dimension

Requirement: FD-3 (Standard, does not require modification at considered level of demand planning advancement).

Two levels are available: Product and product group. A forecast can be entered at both levels, if entered at product group level it is automatically disaggregated to product level using a specified Item allocation key.

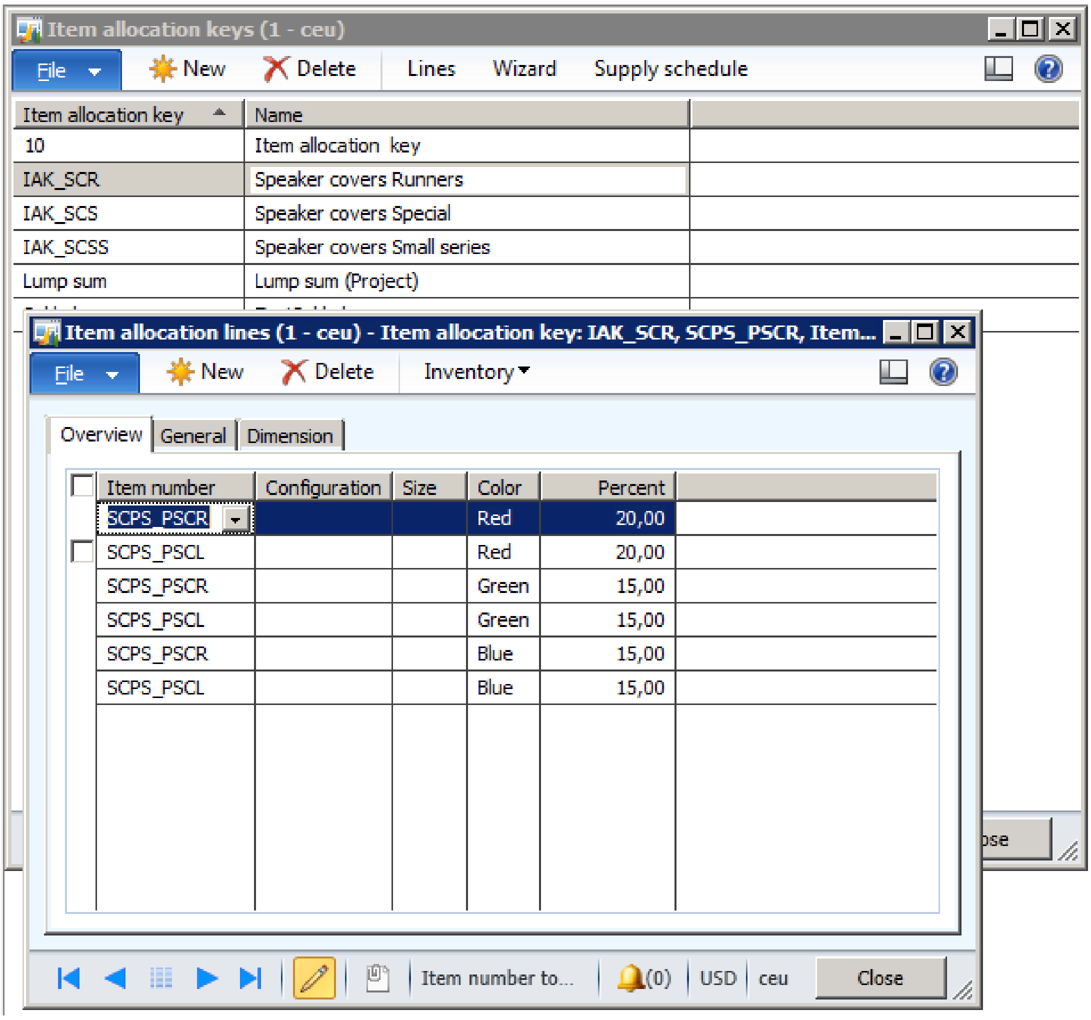


Figure 13: Item allocation key menu and lines for one random key.

7.1.3 Segmentation of geography (customer) dimension

Requirement: FD-4 (Standard, does not require modification at considered level of demand planning advancement).

Two levels are available: Customer and customer group. A forecast can be entered only for specific customer, customer group level is for viewing and managing forecasts at this aggregation level.

7.1.4 Segmentation of time dimension

Requirement: FD-5 (Standard, does not require modification at considered level of demand planning advancement).

A planner can enter forecast for any planning horizon and any periodicity he wants for any dimension and any aggregation level by using methods Period or Key (period allocation key) as described in *Demand Planning and Forecasting Functionality*.

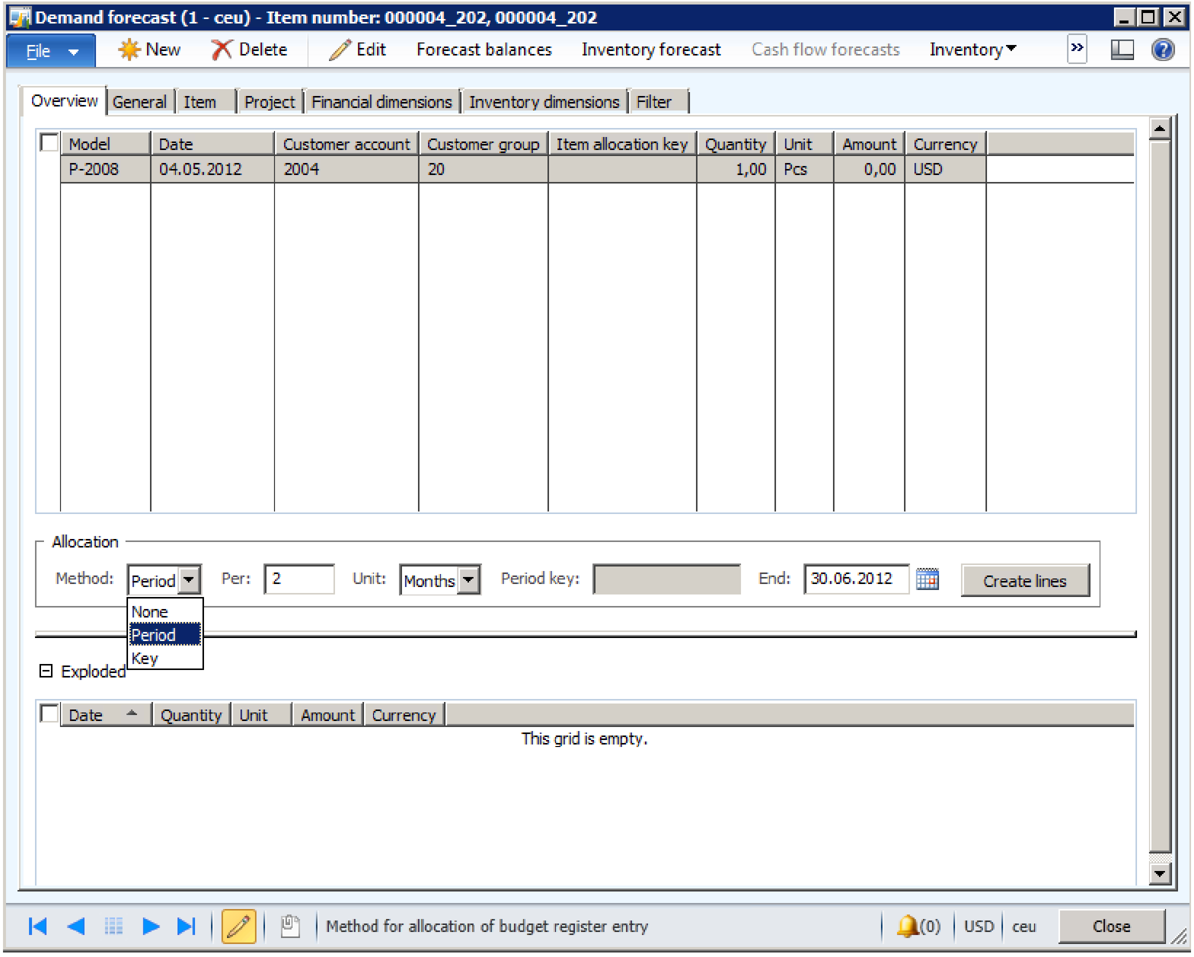


Figure 14: Entering a demand forecast for single item.

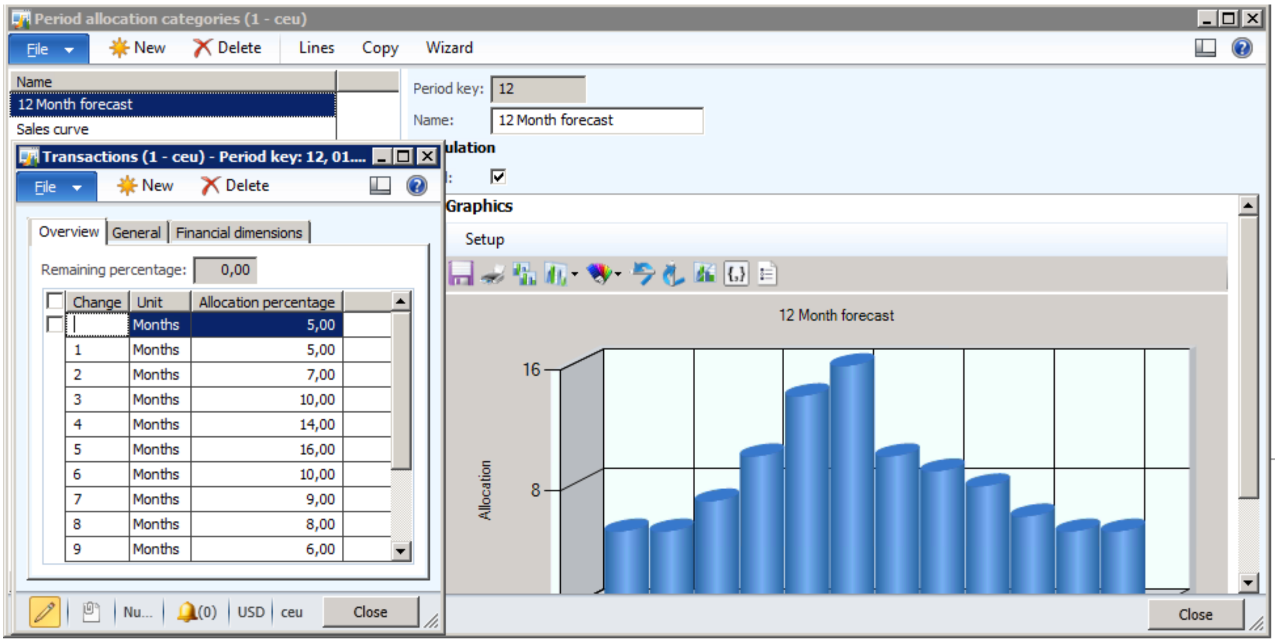


Figure 15: Period allocation key menu and lines for one random key.

7.1.5 Naïve forecasting methods available

Requirement: Partly FF-1 (Customization).

Allocation method *Key* described above can be considered to be equivalent with the simplest naïve forecasting method: Next period demand equals this period demand.

Based on historical demand for this particular dimension and aggregation level, it is possible to calculate a matching Period allocation key so that this key will represent the desirable demand distribution. Together with total historical demand for that period, the system is able to compute a forecast value for each period. E.g. user wants the demand forecast for July and August 2012 be equal the demand of July and August 2011 for a certain item or item group. He or she is then able to start Period allocation key wizard, select the needed demand data for the previous year so that the system calculates the historic monthly demand distribution, total demand for 2011 and therefore the expected demand in all of the month in 2012, including July and August.

See FMS_01.

7.1.6 Calculation of forecast error measurements and generation of forecast error report

Requirement: FF-3, FF-7 and FF-8 (Customization).

It is possible to generate error report for any period of time for any aggregation level for any of two remaining dimensions when the corresponding real demand is known and historical forecast values are available. The report is based on the automatic calculation of mean absolute deviation and tracking signal. Any lines with -6 < TS < 6 are highlighted.

See FMS_02.

7.1.7 Manually inserting a demand forecast

Requirement: FF-13 (Standard).

User choses one of the levels illustrated at Figure 16 and follows one of the procedures described in 7.1.2, 7.1.3 and 7.1.4.

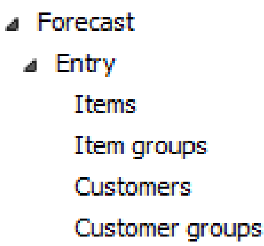


Figure 16: Levels of demand forecast insertion.

7.1.8 Immediate propagation of changes

Requirement: FF-18 (Standard, does not require modification at considered level of demand planning advancement).

Entering a forecast at item group level will result in automatic disaggregation of the forecasting data to item level according to the specified Item allocation key (see Figure 13). Inconsistency is not a problem since it is actually just one higher aggregation level (item group) and entering different forecast values for the same item is not supported.

7.2 Functional Modification Specifications

Current section presents the functional modification specifications (FMS) which were referred to in the previous section. FMS-form itself is taken from the materials provided by Odd Jøran Sagegg and is also used at *TPK4165 ERP/PLM systems*, a course at NTNU where Odd Jøran Sagegg is one of the lecturers. The form is translated into English, since originally the form's headings and other text is in Norwegian.

According to the base solution, two functional modification specifications are needed.

Name FMS_01	**Change applies** Period allocation key
Unit	**Comment**
Date 04.06.2012	**Our reference (reported by)**

Reason:

From solution design: "*Based on historical demand for this particular dimension and aggregation level, it is possible to calculate a matching Period allocation key so that this key will represent the desirable demand distribution. Together with total historical demand for that period, the system is able to compute a forecast value for each period*."

Changes in interface:

Periodic allocation key wizard gets a screen with two options: Standard (continue with the standard functionality) and Corresponding historic period forecasting (continue using new functionality).

Choosing new functionality leads the user to the dialog of choosing appropriate historical demand data and specifying length for one period as well as choosing which periods he or she wants to create a forecast for.

Functional changes:

E.g. user wants the demand forecast for July and August 2012 be equal the demand of July and August 2011 for a certain item or item group. He or she is then able to start Period allocation key wizard, select the needed demand data for the previous year from sales orders so that the system calculates the historic monthly demand distribution as well as total demand for 2011 and therefore the expected demand in all of the month in 2012, including July and August.

Technical description:

Test example:

Estimate		**Order/accept**	
Development*	**Responsible consultant**	**Date**	**Customer sign**
X hours			

Changes after approval are applied below and are approved with new signature.

**Billed on a time basis, it is normally calculated a premium of 50 – 60% to test, implementation and debugging.*

Checkpoints (give details below, if ”Yes”)	**Yes/No**
1. Is there a need for other modifications, successive adjustments in the solution?	
2. Is there a need for updating the data, and possibly evaluated extent of this?	

Name	Change applies
FMS_02	Forecasting error measuring and reporting
Unit	**Comment**
Date	**Our reference (reported by)**
04.06.2012	

Reason:

From solution design: "*It is possible to generate error report for any period of time for any aggregation level for any of two remaining dimensions when the corresponding real demand is known and historical forecast values are available. The report is based on the automatic calculation of mean absolute deviation and tracking signal. Any lines with -6 < TS < 6 are highlighted.*"

Changes in interface:

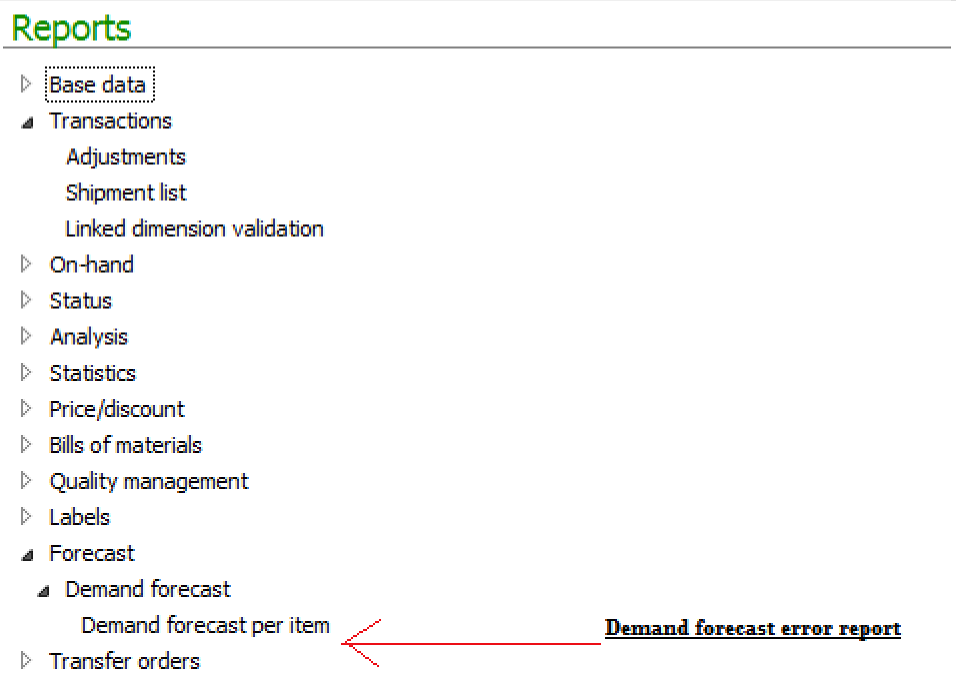


Figure 17: Inventory and warehouse management module

Functional changes:

Demand forecast error report has the same output functionality as any other report function in AX 2012. If the demand for a period is known and historical forecast values are available for the same period, the function is able to compute MAD and TS for all remaining directions (customer and item) and aggregation levels. The report highlights biased forecasts, i.e. those whose TS value does not lie in (-6, 6).

Technical description:

Test example:

Estimate		**Order/accept**	
Development*	**Responsible consultant**	**Date**	**Customer sign**
X hours			

Changes after approval are applied below and are approved with new signature.

**Billed on a time basis, it is normally calculated a premium of 50 – 60% to test, implementation and debugging.*

Checkpoints (give details below, if ”Yes”)	**Yes/No**
1. Is there a need for other modifications, successive adjustments in the solution?	
2. Is there a need for updating the data, and possibly evaluated extent of this?	

8 Industry Opinion

Up until now, the work was mainly theoretical since no case company is associated with this thesis, and as it is described at chapter 6, literature study played a role of business process analysis. The source of empirical information was mainly Microsoft Dynamics AX 2012. In order to add more empirical material to the thesis and at the same time to confirm or disprove the thesis' view on the "best practice" demand planning process and the consequential requirements specification for the demand planning module, it was decided to conduct a couple of short interviews with some relevant Norwegian companies and basically ask the a question: "*Imagine an ideal demand planning system. What functionality would you like it to have?*" The companies contacted were the ones that had cooperation with *NTNU* or Logica, or both, and have in some way expressed a wish for a (better) demand planning system/functionality.

Totally, two companies were interviewed. The first company, which name will remain undisclosed in order not to harm their image, was actually looking for logistics experts in order to get control over their forecasting processes and claimed to be unable to answer the question. In the author's opinion, this only emphasizes the need for an easy-to-use, automated, transparent demand planning system, supporting such requirements from Table 7 as best-fit function and graphical representation of data.

The second company's name is Flexit. It is the largest in Norway producer of ventilation and central vacuum systems. The interviewee was Espen Orderud, logistics controller at the company. The list of functions he came up with is following:

1. Manual insertion of forecasts, since automatic forecasting leads to losing control over the process. He claimed it was too challenging to get familiarized with all the necessary theory to use the automation and still maintain control.
2. Flexible overview of historical demand with opportunity to twist and turn the data.
3. Segmentation and aggregation along the product dimension
4. Collaborative forecasting together with sales department
5. Integration with ERP system, especially with *Master Planning* module

Again we can see a need of simple, automated best-fit option which does not require much theoretical knowledge about forecasting to be used. Graphical representation of data does also seem to fit the list well. Points 2 and 3 are about segmentation and aggregation of historical demand data and forecast results; these requirements are included in the requirements specification tables. Number 4 is discussed in the proposed framework (*Collaborative forecasting*) and is in a way a "free" requirement that is by default implemented in AX 2012: ERP system being enterprise-wide, allows employees from sales department to have access to forecasting if the permissions are properly configured. The difficulty here is that AX 2012 functionality does not support collaborative forecasting in a good and transparent fashion so that e.g. it is difficult for responsible forecaster to create a joint forecast out of several fragmented ones coming from for example different sales departments. We see that the need of requirements FF-15 and FF-16 from Table 7 is supported by this interview. The last requirement is available by default in standard AX as it is described at the end of section *3.1.3.2 Demand Planning and Forecasting Functionality*.

The conclusion here will be that these short interviews have further strengthened results of the analysis done in the literature study and the following development of requirements specification. The functionality anticipated by the interviewees in the Norwegian industry is either explicitly written down in the requirements specification tables or is implied by the decision to incorporate Demand Planning Module seamlessly into Microsoft Dynamics AX 2012.

9 Conclusion

Nowadays it is difficult to speak about business without mentioning technology, especially enterprise systems (ES) and more specifically the enterprise resource planning (ERP) systems and their opportunities to support current industrial and supply chain management (SCM) processes. Demand planning is one of such processes and many other decisions in an organization depend on it, their quality is therefore dependent on demand planning's quality.

This report predominantly concerns ERP systems, especially Microsoft Dynamics AX 2012, and their role in SCM as well as demand planning process seen in a supply chain perspective. On the basis of literature study a system development process has taken place resulting in functional requirements specification for a demand planning module, analysis of its fit for AX 2012 and the following attempt to solve some of the requirements by building them into Dynamics AX. Finally, a couple of interviews with relevant Norwegian companies were conducted in order to add more empirical data to the research and check the correctness of the theoretical findings, and both was done with a success as it is described at chapter 8.

The thesis' results can be summarized by answering the research questions asked at the *Introduction* chapter. RQ1 sounds like "*What is the current state of the art demand planning and forecasting process?"* The question is mainly answered through the proposed demand planning framework which is considered the main theoretical finding of this work and is intended to describe exactly a state-of-the-art demand planning process. The framework consists of four major steps including (i) understanding of purpose, benefits and conditions of demand planning process, (ii) structuring data in a way that a quality forecasting process can be run, (iii) the process itself which uses qualitative, quantitative and collaborative approaches and (iv) critically reviewing and analyzing the demand planning process and looking for the ways to improve it. The proposed framework is intended to support collaborative forecasting both inside and outside an enterprise. This framework is considered the main contribution to knowledge done by this thesis. Though it is a rather well-thought-out product, incorporating three other demand planning framework and CPFR process elements as well as other findings done during the literature study, it is suggested to further work on it in order to make the framework even more clear and understandable. Author hopes that now, and especially in the case the framework will be further enhanced, any enterprise considering implementing a state-of-the-art demand planning process will find a great help at this work.

Having the answers on RQ1 in mind, let us consider RQ2: "*What are the requirements for Demand Planning Module which is able to support the current state of the art demand planning process?"* The answer to that follows directly from the description of demand planning process summarized in the proposed framework and is presented at section *5.1 General Functional and Non-functional Requirements*. All the requirements postulated at Table 7 are a direct result of literature study and roughly follows the structure of the proposed common demand planning framework. The requirements from this table are considered generic and system-independent suited therefore for any demand planning software module. In order to improve these requirements specification one must first improve the literature study and especially the proposed common framework since it is the base for the specification.

The last research question is the most extensive one. It sounds as following: "*Which of the requirements from RQ2 are relevant for Microsoft Dynamics AX 2012, and how can they be implemented in the ERP system?*" RQ3 is attempted to be covered by section *5.2 Microsoft Dynamics AX 2012 Specific Requirements Specification* and chapter *7 User-oriented Solution Design*. It was found that AX 2012 had many functionality gaps when it comes to supporting current state-of-the-art demand planning process and some of these gaps were tried to be covered by the user-oriented solution design functional modification specifications presented at chapter *7*. Usually, such documents are developed by highly-trained professionals at consultancy companies. This attempt is considered to be very limited first of all due to the author's lack of sufficient training and shortage of in-depth understanding of the processes' relations in AX 2012. Still, looking at the whole picture, the question was answered, but the limitation described above is considered the main limitation of this thesis. It is therefore proposed that the next attendees to this and related assignments get extensible training in the ERP or any other complex tool they are going to research on.

Goals and success criteria achievement

The thesis' goals are defined as follows:

- Successfully answer all the research questions
- Greatly contribute to Logica's effort to develop additional demand planning functionality for Microsoft Dynamics AX 2012
- Get an even deeper understanding of the main topics of this thesis and in this way prepare for the future career
- Train to work evenly, systematically and scientifically
- Try out what a "real life" tasks might look like and train to solve them

As elaborated above, all the research questions were answered, but the answers found have their, sometimes very significant, limitations. The goal is therefore achieved, but not to a full extent. By answering the research questions and holding as close as possible to Logica's procedures and documentation, author hopes to have made at least a little step towards the development of appropriate demand planning functionality for Microsoft Dynamics AX 2012 and thus was of help to Logica and their efforts. And the last three goals involve my own learning and self-development and were undoubtedly reached during the work with this thesis.

The thesis' success criteria are following:

- Grade B or better
- Positive feedback from the supervisors
- The thesis' result is considered a very significant improvement of the foregoing specialization project from the previous semester
- Feeling of a well-accomplished task
- Feeling of being well-prepared for the future career in this field

The first two criteria cannot be evaluated before the thesis is handed in and examined by the supervisors. I can give a try, however, at evaluating the third one. My thesis is built on my own project from the previous semester and this thesis is thought to improve my past work which I consider it does. The two last criteria are subjective and can be evaluated right at the end of the thesis. I feel the task well-structured and well-thought-out and I have learned a lot, but, as discussed above, there are identified a number of limitations to the work. All in all, I consider the last two criteria achieved, but not to the same extent as I hoped they would be.

Distant future results expectations

To accomplish this report with some positive thinking, I would like to express my vision of the results that would be achieved at distant future at this field. While some researchers (Jacobs and Weston Jr, 2007) express their expectations about increased usage of artificial intelligence (AI) and simulation in future ERP systems and hope that the academic community will take a more active role in this process, the others are already conducting research in that area (Efendigil et al., 2008). Hopefully, these expectations come true also at this particular field, and AI will be able to take good care of much greater part of demand planning process than it is possible now, and there will be less companies frustrated over the automation, advanced forecasting methods and even at the demand planning process at all. I hope to have done at least a little step in that direction.

References

Demand Pattern Classification & Forecasting [Online]. Global Supply Chain Laboratory, Texas A&M University. Available: http://www.slideshare.net/Bobtb/demand-pattern-classification [Accessed 15.12 2011].

2009. DEMAND PLANNING: HOW TO REDUCE THE RISK AND IMPACT OF INACCURATE DEMAND FORECASTS. *SUPPLY CHAIN EXPERT SERIES* [Online]. Available: http://www.kinaxis.com/whitepapers/Demand-Planning.cfm.

2011. Oxford Dictionaries. Oxford University Press.

AKKERMANS, H. A., BOGERD, P., YÜCESAN, E. & VAN WASSENHOVE, L. N. 2003. The impact of ERP on supply chain management: Exploratory findings from a European Delphi study. *European Journal of Operational Research,* 146**,** 284-301.

ALFNES, E. 2011. Enterprise Resource Planning. The Department of Production and Quality Engineering: Norwegian University of Science and Technology.

ARCHER, B. H. 1980. Forecasting demand: Quantitative and intuitive techniques. *International Journal of Tourism Management,* 1**,** 5-12.

ARIAS, E. 2012. *Microsoft Dynamics AX 2012 Services and (Application Integration Framework) AIF architecture* [Online]. Available: http://axwonders.blogspot.no/2012/01/microsoft-dynamics-ax-2012-services-and.html [Accessed 09.06 2012].

ARNOLD, J. R. T., CHAPMAN, S. N. & CLIVE, L. M. 2008. *Introduction to materials management,* Upper Saddle River, N.J., Pearson Prentice Hall.

ATTARAN, M. & ATTARAN, S. 2007. Collaborative supply chain management. *Business Process Management Journal,* 13**,** 390-404.

BITITCI, U. 2003. ERP implementation.

BLACKSTONE JR., J. H. & COX, J. F. 2005. APICS Dictionary. 11th ed.: APICS: The Association for Operations Management.

BLOCHER, J. D., MABERT, V. A., SONI, A. K. & VENKATARAMANAN, M. A. 2004. Forecasting. Including an Introduction to forecasting using the SAP R/3 System. Available: http://www.slideshare.net/Bobtb/demand-management-forecasting [Accessed 15.12.2011].

BOND, B., GENOVESE, Y., MIKLOVIC, D., WOOD, N., ZRIMSEK, B. & RAYNER, N. 2004. ERP Is Dead — Long Live ERP II. *Strategic Planning* [Online].

BURNETT, J. 2011. *Most Manufacturers Customize ERP Systems* [Online]. Available: http://www.twinengines.com/industry-insights/knowledge-base/erp-extensions.aspx [Accessed 18.12 2011].

BUTT, W. 2009. *Demand Planner Discontinuation Notice for Microsoft Dynamics AX, Microsoft Dynamics GP and Microsoft Dynamics NAV* [Online]. Available: http://waqasb.blogspot.com/2009/12/demand-planner-discontinuation-notice.html [Accessed 08.11.11.

CAGLIANO, R., CANIATO, F. & SPINA, G. 2003. E-business strategy: How companies are shaping their supply chain through the Internet. *International Journal of Operations & Production Management,* 23**,** 1142-1162.

CHALLA, R. & SHUKLA, S. 2010. Bristlecone Perspective: Improving Demand Forecasting. *Bristlecone* [Online].

CHOPRA, S. & MEINDL, P. 2010. Supply chain management: strategy, planning, and operation.

COGHLAN, A. 2010. *A Little Book of R for Time Series* [Online]. Available: http://a-little-book-of-r-for-time-series.readthedocs.org/en/latest/index.html# [Accessed 15.12.2011.

DAVENPORT, T. H. 1998. Putting the Enterprise into the Enterprise System. *Harvard Business Review*.

DHAWAN, S. 2010. *Research Methodology for Business and Management Studies,* Delhi, IND, Global Media.

EFENDIGIL, T., ÖNÜT, S. & KAHRAMAN, C. 2008. A decision support system for demand forecasting with artificial neural networks and neuro-fuzzy models: A comparative analysis. *Expert Systems with Applications,* 36**,** 6697-6707.

FILDES, R. 1979. Quantitative Forecasting -- The State of the Art: Extrapolative Models. *The Journal of the Operational Research Society,* 30**,** 691-710.

FINDTHEBEST. 2012. *Microsoft Dynamics AX 2012 vs SAP Business Suite* [Online]. Available: http://accounting-software.findthebest.com/compare/72-74/Microsoft-Dynamics-AX-2012-vs-SAP-Business-Suite# [Accessed 09.06 2012].

FLIDES, R., GOODWIN, P., LAWRENCE, M. & NIKOLOPOULOS, K. 2006. Producing more efficient demand forecasts. *Working Paper Series.* Claverton Down, Bath: University of Bath School of Management.

FLIEDNER, G. 2003. CPFR: An emerging supply chain tool. *Industrial Management + Data Systems,* 103**,** 14-21.

FROHLICH, M. T. & WESTBROOK, R. 2002. Demand chain management in manufacturing and services: web-based integration, drivers and performance. *Journal of Operations Management,* 20**,** 729-745.

GERINER, P. T. & ORD, J. K. 1991. Automatic forecasting using explanatory variables: A comparative study. *International Journal of Forecasting,* 7**,** 127-140.

HARRISON, T. P., LEE, H. L., NEALE, J. J. & WHANG, S. 2004. e-Business and Supply Chain Integration

The Practice of Supply Chain Management: Where Theory and Application Converge. Springer US.

HIPPERT, H. S., BUNN, D. W. & SOUZA, R. C. 2004. Large neural networks for electricity load forecasting: Are they overfitted? *International Journal of Forecasting,* 21**,** 425-434.

JACOBS, R. F. & WESTON JR, T. F. C. 2007. Enterprise resource planning (ERP)—A brief history. *Journal of Operations Management,* 25**,** 357-363.

KILGER, C. & WAGNER, M. 2008. Demand Planning

Supply Chain Management and Advanced Planning. *In:* STADTLER, H. & KILGER, C. (eds.). Springer Berlin Heidelberg.

LEKANOV, A. 2011. *Logistics Planning Module for Microsoft AX: Demand Planning.* Norwegian University of Science and Technology.

MAKRIDAKIS, S. 1986. The art and science of forecasting: An assessment and future directions. *International Journal of Forecasting,* 2**,** 15-39.

MARTIN, C. A. & WITT, S. F. 1989. Forecasting tourism demand: A comparison of the accuracy of several quantitative methods. *International Journal of Forecasting,* 5**,** 7-19.

MATHEWS, B. P. & DIAMANTOPOULOS, A. 1986. Managerial intervention in forecasting. An empirical investigation of forecast manipulation. *International Journal of Research in Marketing,* 3**,** 3-10.

MCCARTHY, T. & GOLICIC, S. 2002. Implementing collaborative forecasting to improve supply chain performance. *International Journal of Physical Distribution & Logistics Management,* 32**,** 431-431.

MENTZER, J. T., DEWITT, W., KEEBLER, J. S., MIN, S., NIX, N. W., SMITH, C. D. & ZACHARIA, Z. G. 2001. DEFINING SUPPLY CHAIN MANAGEMENT. *Journal of Business Logistics,* 22**,** 1-25.

MICROSOFT. 2006. MICROSOFT DYNAMICS™ AX 4.0, COURSE 8623A: DEVELOPMENT I TRAINING. *Microsoft Official Training Materials for Microsoft Dynamics™* [Online].

MICROSOFT. 2011. *X++ Language Programming Guide [AX 2012]* [Online]. Available: http://msdn.microsoft.com/en-us/library/aa867122.aspx [Accessed 08.10.11.

MICROSOFT. 2012a. *Layers [AX 2012]* [Online]. Available: http://technet.microsoft.com/en-us/library/aa851164.aspx [Accessed 09.06 2012].

MICROSOFT. 2012b. *Microsoft Dynamics AX: Powerful. Agile. Simple.* [Online]. Available: http://www.microsoft.com/en-us/dynamics/erp-explore-ax-capabilities.aspx [Accessed 09.06 2012].

MOLLER, C. 2005. ERP II: a conceptual framework for next-generation enterprise systems? *Journal of Enterprise Information Management,* 18**,** 483-497.

NUNAMAKER JR., J. F. & MINDER, C. 1990. Systems development in information systems research. *System Sciences.* Hawaii.

ORACLE. 2006. *Oracle and Demantra* [Online]. Available: http://www.oracle.com/us/corporate/acquisitions/demantra/index.html [Accessed 10.06 2012].

PEARLSON, K. E. & SAUNDERS, C. S. 2009. *Strategic Management of Information Systems,* Asia, John Wiley & Sons, Inc.

PEREIRA, B. D. B., COQUEIRO, R. C. O. & PERROTA, A. H. V. 1989. Experience In Combining Subjective And Quantitative Forecas. *Journal of Forecasting,* 8**,** 343-343.

PHOPHALIA, A. K. 2010. *Modern Research Methodology : New Trends and Techniques,* Jaipur, IND, Global Media.

SACHDEVA, J. K. 2009. *Business Research Methodology,* Mumbai, IND, Global Media.

SADLER, I. 2007. *Logistics and supply chain integration,* Los Angeles, SAGE.

SCDIGEST. 2008. The Eight Steps of the Forecasting Process Using Demand Planning Software. Available: www.scdigest.com.

SCDIGEST. 2009. The Supply Chain Digest Letter. Available: www.scdigest.com/letter.

SIMATUPANG, T. & SRIDHARAN, R. 2004. Benchmarking supply chain collaboration: An empirical study. *Benchmarking,* 11**,** 484-503.

SØNDERGAARD, H. 2006. Fremdrift: Introduksjon til metoden. WM-data.

VIK, R. K. 2010. *Logistics Planning Module for Microsoft AX: Demand Planning.* Project thesis, Norwegian University of Science and Technology.

W3SCHOOLS. 2012. *Introduction to XML* [Online]. Available: http://www.w3schools.com/xml/xml_whatis.asp [Accessed 09.06 2012].

WAGNER, M. 2005. Demand Planning

Supply Chain Management and Advanced Planning. *In:* STADTLER, H. & KILGER, C. (eds.). Springer Berlin Heidelberg.

WANDNER, S. A. & VAN ERDEN, J. D. 1979. Estimating the demand for international tourism using time series analysis.

WILLIAMSON, E. A., HARRISON, D. K. & JORDAN, M. 2004. Information systems development within supply chain management. *International Journal of Information Management,* 24**,** 375-385.

WYLIE, L. 1990. A vision of the next-generation MRP II.

Appendix A: Preliminary Report

NTNU, IPK, TPK4900

Preliminary report

Logistics Planning Module for Microsoft AX: Demand Planning

NTNU – Trondheim
Norwegian University of
Science and Technology

logica
be brilliant together

Stud. techn. Alexey Lekanov
06.02.2012

Preface

This preliminary report is a part of a master thesis taken at the second semester of the fifth year of study at *Engineering and ICT*, a master's degree program at *Norwegian University of Science and Technology* (NTNU). The master thesis is the course *TPK4900* at *Department of Production and Quality Engineering* (IPK) and is conducted in collaboration with *Logica*, a business and technology service company. Thesis' supervisors are Erlend Alfnes from IPK and Odd Jøran Sagegg from Logica. This report is meant to concretize the thesis' tasks and provide an overview and analysis of the assignment as well as describe the plan of action for how this assignment is to be solved, including tasks and research questions, work breakdown structure (WBS) and work packages description and a Gantt diagram with known major milestones.

The thesis' topic is *Logistics Planning Module for Microsoft AX: Demand Planning*.

____

Stud. techn. Alexey Lekanov

Table of contents

1 Introduction

Demand information has a major impact on a number of decisions taken within a supply chain or any of its members (Efendigil et al., 2008, Chopra and Meindl, 2010), for these decisions to be correct it is required that the information they are based on is correct. In this way successful demand planning can be seen as an important component of an organization's and whole supply chain's competitiveness.

Information technology being a critical component of almost every business process today (Pearlson and Saunders, 2009), can be considered another important competitive ingredient, while enteprise resource planning (ERP) systems are an important class of IT software different organizations use to enhance their business processes and the processes' integration with each other. One can see the demand planning as one of such processes and it would then be reasonable to think that a good ERP system should have support for it. This point of view is undirectly supported by the fact that it is common for leading ERP systems to have demand planning and forecasting functionality (e.g. SAP and Oracle), while the Microsoft's ERP solution (Dynamics AX) has limited support for demand planning (Alfnes, 2012). AX has functionality to process already generated forecasts, but cannot generete them itself which is an unfortunate situation for the competitive position of this system, compared to other ERP solutions, and therefore also harmful for competiteveness of organizations offering Microsoft Dynamics AX to its clients, including Logica as one of such organizations.

This thesis is a continuation of the specialization project (Lekanov, 2011) from the previous semester. Main goal of the work is to contribute to Logica's effort to develop the needed demand planning functionality for Microsoft Dynamics AX by describing requirements specification for the future module and developing other relevant documentation as well as a prototype to illustrate some of the demand planning module's functionality. This report will present futher thesis description, including tasks, research questions, workpackages and their schedule and goals and success criteria of the thesis.

2 Thesis' tasks and research questions

The task consists of developing a tool for forecasting in ERP system Microsoft Dynamics AX. There should be developed functionality for forecasting based on historical data and collaborative models. The data are retrieved from the ERP system or other relevant sources, and it should be possible to update the parameters of the system from the improvement proposal which is automatically generated. There should be developed a functional and technical design for such a tool. The solution should be online and be built on standard Microsoft technology.

Thesis' main tasks as they are stated in the assignment text:

8. Provide an overview of relevant theory and best practices within forecasting and demand planning.
9. Create a general requirements specification for forecasting and demand planning functionality.
10. Examine the existing functionality, as well as opportunities and limitations of forecasting in AX 2012.
11. Specify the overall product-oriented requirements specification for the new demand planning module in AX 2012.
12. Create user-oriented solution design for the new demand planning module in AX 2012.
13. Create development documentation (Functional Modification Specifications) for the new demand planning module in AX 2012.
14. Create prototype on chosen functionality in AX 2012.

The abovementioned tasks and description is taken from the assignment text and is a starting point for formulating the research questions and analyzing the assignment, especially clarifying the way it is to be solved.

After some consideration the following research questions (RQs) are chosen as the starting point for the thesis:

- RQ1: *What is the current state of the art demand planning and forecasting process?*
- RQ2: *What are the requirements for Demand Planning Module which is able to support the current state of the art demand planning process?*
- RQ3: *Which of the requirements from RQ2 are relevant for AX 2012 and how can they be implemented in the ERP system?*

First two of the thesis' objectives are similar to the objectives considered in the foregoing specialization project (Lekanov, 2011) at Autumn 2011 and a lot of input can be taken from there to start with. That is the reason for the similarity of research questions 1 and 2 with the research questions from the specialization project. The objectives 3 – 7, however, are new for this thesis and require relatively deep understanding of AX 2012, these facts are reflected by creation an additional research question (RQ3) which implicitly implies studying of AX 2012.

Having the research questions at hand as well as the original tasks of the thesis it is now possible to plan the work which needs to be done in order to answer the research questions and complete the objectives.

3 Thesis' work packages

To accomplish these subtasks in a proper way the following work has to be done:

1. Analysis and (this) preliminary report.
2. Methods.
3. Theory study.
4. Collecting empirical data.
5. Developing.
6. Writing main report.
7. Project management.

These work packages are illustrated in work breakdown structure (WBS) at Figure 18. For the time schedule and major milestones see the Gantt diagram at Figure 19.

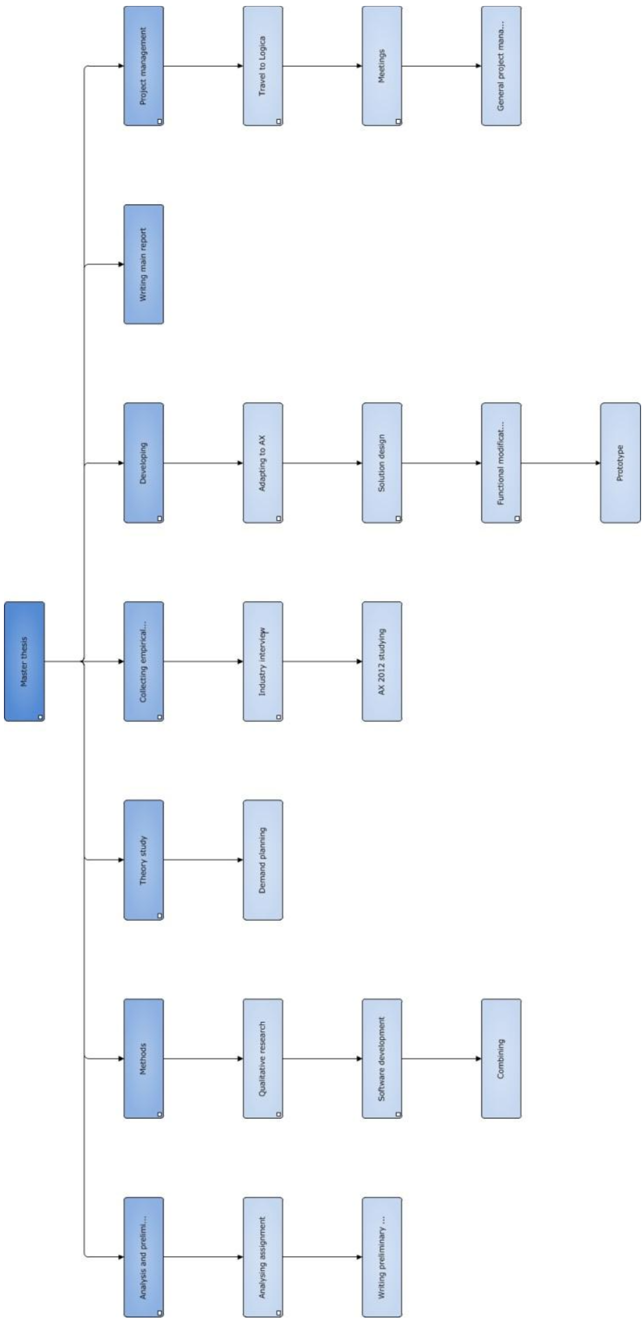


Figure 18: WBS of the master thesis.

3.1 Work packages description

A description of each of the work packages is provided below. Totally, the workload is estimated to be equal 900 hours since this master thesis is a 30 sp course at NTNU (Studieavdelingen, 2005) which gives about 40 hours per week.

3.1.1 Analysis and (this) preliminary report

Analyzing the assignment text and writing this report as a starting point for the master thesis.

3.1.2 Methods

Suitable methods for conducting this thesis are to be found. The thesis is a combination of qualitative research and a software development project, i.e. suitable methods for both are to be found and a suitable combination of these methods is to be thought out and applied to this thesis. This work package should be completed as soon as possible to make the rest of the work more streamlined and logical.

3.1.3 Theory study

The fields of forecasting and demand planning are to be studied further to increase the authors understanding and capabilities in this area. Further research proposals from Lekanov (2011) are to be considered.

3.1.4 Collecting empirical data

The work here can be separated into two categories:

1. Collecting empirical data from the Norwegian industry (through e.g. interviews) to further increase the authors inside into the field.
2. Studying AX 2012 which is absolutely required for answering RQ3 and completing remaining work packages. Hopefully, Logica will be able to provide assistance at this point.

3.1.5 Developing

This work package includes improving the generic requirements specification for the demand planning module from the specialization project done in the previous semester, adapting it for the AX 2012 and creating user-oriented solution design and functional modification specifications. Creating a modules prototype to illustrate some of the proposed functionality is the last point of this work package.

3.1.6 Writing main report

All the work done in this project is to be documented in the main report which is also the main basis for the thesis' grading at NTNU.

3.1.7 Project management

This thesis is conducted as a project and will mainly be managed by its author, i.e. Alexey Lekanov, but it is reasonable to expect some assistance from the supervisors. The thesis' current time schedule is illustrated at Figure 19 below.

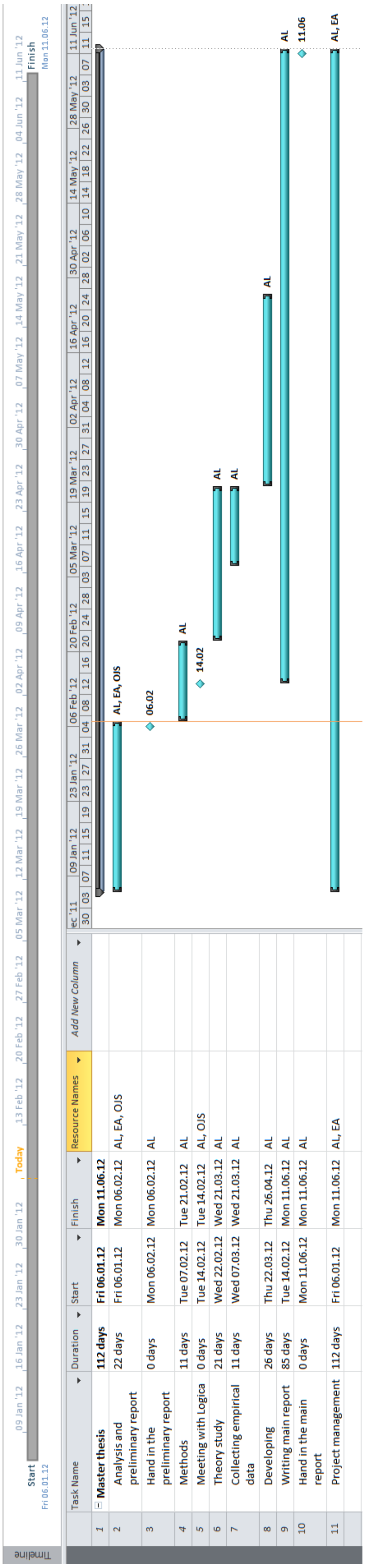


Figure 19: Gantt diagram for the thesis. Diamonds represent thesis' major milestones. Resources: AL – Alexey Lekanov, EA – Erlend Alfnes, OJS – Odd Jøran Sagegg.

4 Goals

There are several goals for this thesis:

- Successfully answer all the research questions
- Greatly contribute to Logica's effort to develop additional demand planning functionality for Microsoft Dynamics AX 2012
- Get an even deeper understanding of the main topics of this thesis and in this way prepare for the future career
- Train to work evenly, systematically and scientifically
- Try out what a "real life" tasks might look like and train to solve them

5 Success criteria

The thesis can be considered fully successful if all the following criteria are met:

- Grade B or better
- Positive feedback from the supervisors
- The thesis' result is considered a very significant improvement of the foregoing specialization project from the previous semester
- Feeling of a well-accomplished task
- Feeling of being well-prepared for the future career in this field

References

ALFNES, E. 2012. Masteroppgave, våren 2012. Trondheim.

CHOPRA, S. & MEINDL, P. 2010. Supply chain management: strategy, planning, and operation.

EFENDIGIL, T., ÖNÜT, S. & KAHRAMAN, C. 2008. A decision support system for demand forecasting with artificial neural networks and neuro-fuzzy models: A comparative analysis. *Expert Systems with Applications,* 36**,** 6697-6707.

LEKANOV, A. 2011. *Logistics Planning Module for Microsoft AX: Demand Planning.* Norwegian University of Science and Technology.

PEARLSON, K. E. & SAUNDERS, C. S. 2009. *Strategic Management of Information Systems,* Asia, John Wiley & Sons, Inc.

STUDIEAVDELINGEN. 2005. Planlegging av semesteret – Veiledning for semesterplan. [Accessed February 05].

Appendix B: Static and adaptive Time-series

Static Time-series

Static time-series methods do not take into account new demand observations during a forecasting period. Using following denomination (here and in the section Adaptive Time-series):

- L = estimate of level at period 0 (zero)
- T = estimate of trend
- S_t = estimate of seasonal factor for period t
- D_t = actual observed historical demand in period t
- F_t = demand forecast for period t

We get the formula for forecasting demand:

$$F_t = (L + t \cdot T) \cdot S_t$$

To compute L and T a linear regression is run on deseasonalized demand pattern, which is the demand pattern we would see if no seasonality were present. Then the estimate for seasonal factors is calculated through a ratio of actual and deseasonalized demand. After L, T and S_t's are known, we can use the formula directly.

Adaptive Time-series

Adaptive techniques, compared to the static ones, use the incoming demand observations to update the estimates in the forecasting model.

Moving average

Moving average is often considered the simplest time-series forecasting method and it can be used when no trend or seasonality is observed on the demand pattern, which means:

Systematic component = level

The forecast is represented by the average demand of N foregoing periods:

$$F_{t+n} = F_{t+1} = L_t = (D_t + D_{t-1} + ... + D_{t-N+1}) / N$$

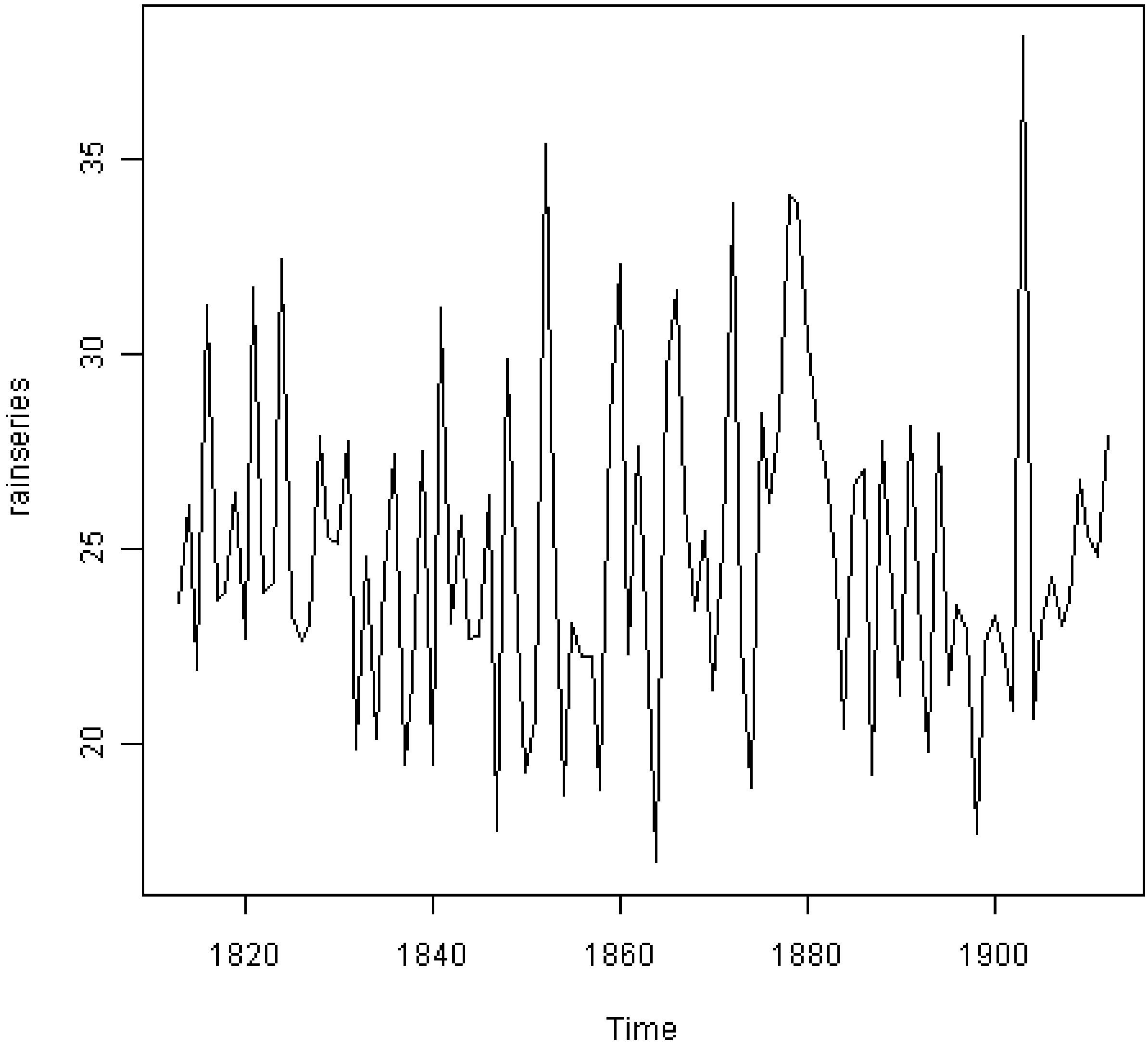
It is known that this method will underforecast in times of increasing demand since the weight of each of the preceding periods is equal regardless of its age. From this point of view it is more appropriate to use exponential smoothing.

Simple exponential smoothing

Analogically with moving average technique, this method is used when no trend or seasonality is observed, i.e.:

Systematic component = level

Such demand pattern, with no clearly observable trend or seasonality, though a huge random component, can for instance look like it is illustrated in Appendix B figure 1.



Appendix B figure 1: Demand pattern with no clearly observable trend or seasonality (Coghlan, 2010)

The formula for the simple exponential smoothing is as follows:

$$F_{t+n} = F_{t+1} = L_t = \alpha \cdot D_t + (1-\alpha) \cdot L_{t-1}$$

We compute L_0 (the starting point) as the average demand of N previous periods: $L_0 = \frac{\sum_{i=1}^{N} D_i}{N}$

Constant α here is a smoothing constant ($0 < \alpha < 1$) which represents how much the current observation of demand is weighted compared to the previous estimates, and is often assigned value between 0.1 – 0.2 (Archer, 1980), to give a stable forecast not extremely responsive to recent observations. Clearly, when $\alpha = 0$ simple exponential smoothing becomes a moving average method while $\alpha = 1$ gives a naïve forecast.

Trend-corrected exponential smoothing (Holt's model)

Holt's model can be applied on a demand pattern with observable trend, but no seasonality, i.e.:

Systematic component = level + trend

For illustration of such pattern see Appendix B figure 2.

Appendix B figure 2: Demand pattern with observable trend (Coghlan, 2010)

Due to the trend component, F_t and F_{t+n} are not equal in this case so that:

$$F_{t+1} = L_t + T_t \quad \text{and} \quad F_{t+n} = L_t + n \cdot T_t$$

To calculate the starting values of level and trend estimates (L_0 and T_0), the linear regression is run on the demand pattern. Then, after a new demand is observed, the estimates are updated by the following formulas:

$$L_t = \alpha \cdot D_t + (1-\alpha) \cdot (L_{t-1} + T_{t-1}) \quad \text{and} \quad T_t = \beta \cdot (L_t - L_{t-1}) + (1-\beta) \cdot T_{t-1}$$

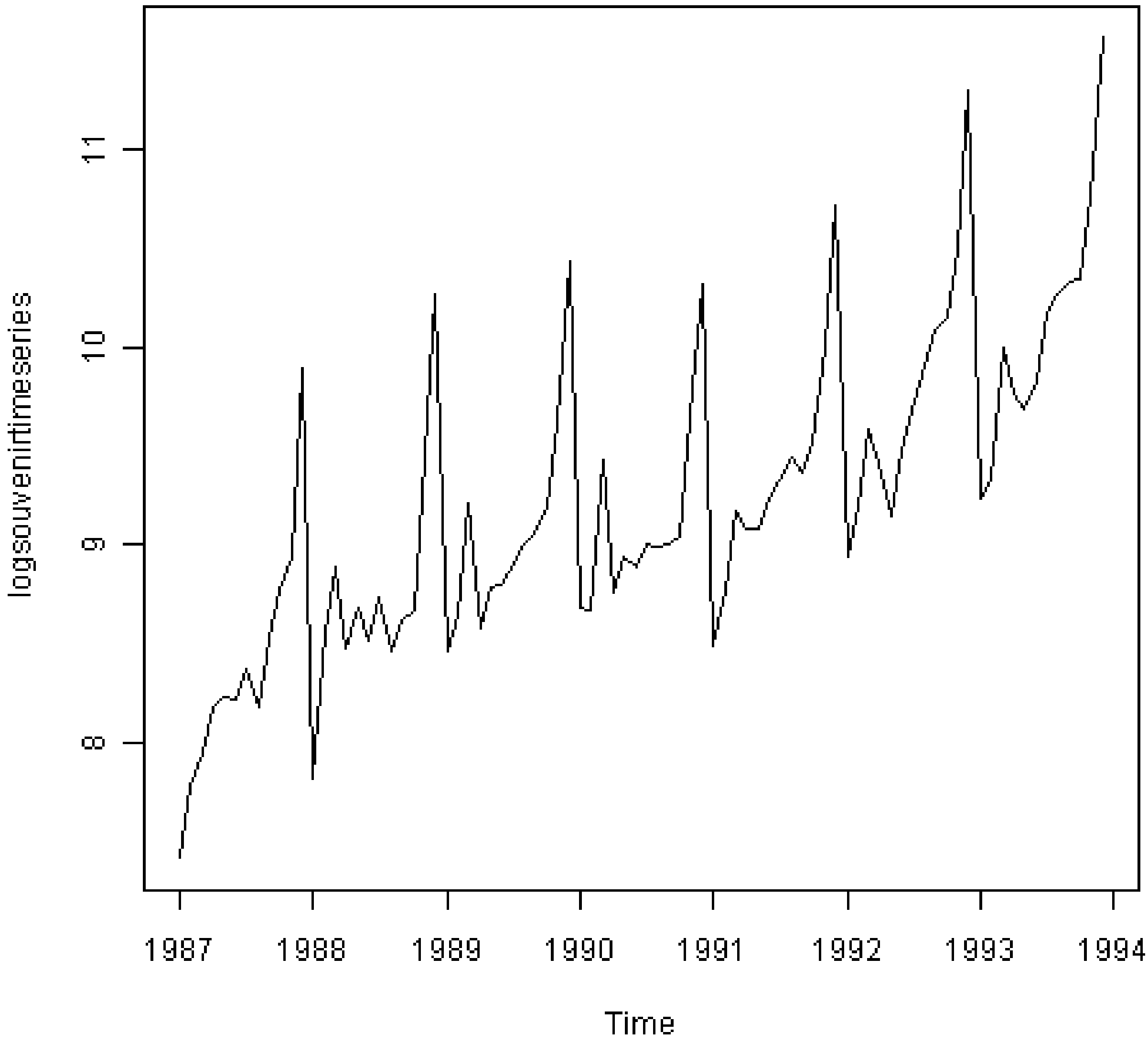
The constant α is the same as before and β is a smoothing constant for the trend (0 < α, β < 1).

Trend- and seasonality-corrected exponential smoothing (Winter's model)

The final adaptive exponential smoothing method described here is suited for demand patterns where both trend and seasonality is observed, which means:

*Systematic component = (level + trend) * seasonality*

The presence of both trend and seasonality in a demand pattern can e.g. look like in Appendix B figure 3.



Appendix B figure 3: Demand pattern with clearly observable trend and seasonality (Coghlan, 2010)

So that F_t and F_{t+n} are now as follows:

$$F_{t+1} = (L_t + T_t) \cdot S_{t+1} \qquad \text{and} \qquad F_{t+n} = (L_t + n \cdot T_t) \cdot S_{t+n}$$

Seasonality means the demand pattern is periodically repeated (if the trend is neglected). Suppose there are p such periods thus, there are p initial seasonal factors. The starting values for the estimates of level, trend and seasonal factors (L_0, T_0 and S_1, S_2, …, S_p) are computed by means of the procedure shortly described in "*Static time-series methods*"-section (0). After observing demand for the period t, the following formulas are applied to update the estimates:

$$L_t = \alpha \cdot (D_t / S_t) + (1-\alpha) \cdot (L_{t-1} + T_{t-1})$$

$$T_t = \beta \cdot (L_t - L_{t-1}) + (1-\beta) \cdot T_{t-1}$$

$$S_{t+p} = \gamma \cdot (D_t / S_t) + (1-\gamma) \cdot S_t$$

Constants α and β are the same as before and a new constant γ is added, which is a smoothing constant for the seasonal factor and 0 < α, β, γ < 1.

References

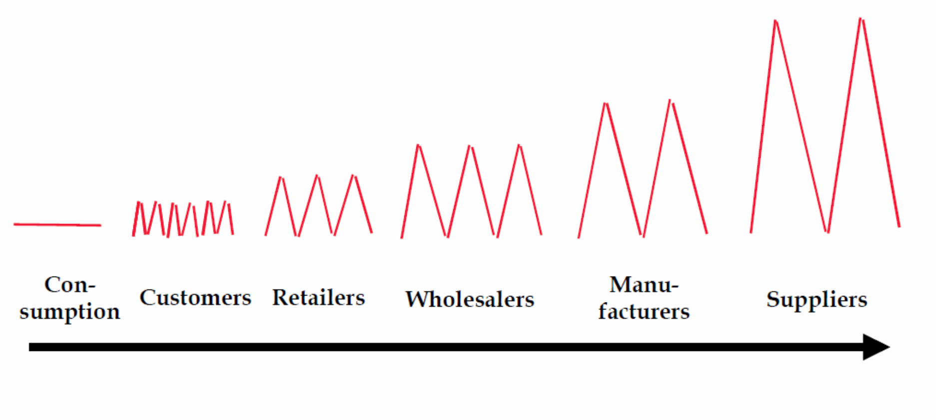
ARCHER, B. H. 1980. Forecasting demand: Quantitative and intuitive techniques. *International Journal of Tourism Management,* 1**,** 5-12.

CHOPRA, S. & MEINDL, P. 2010. Supply chain management: strategy, planning, and operation.

COGHLAN, A. 2010. *A Little Book of R for Time Series* [Online]. Available: http://a-little-book-of-r-for-time-series.readthedocs.org/en/latest/index.html# [Accessed 15.12.2011.

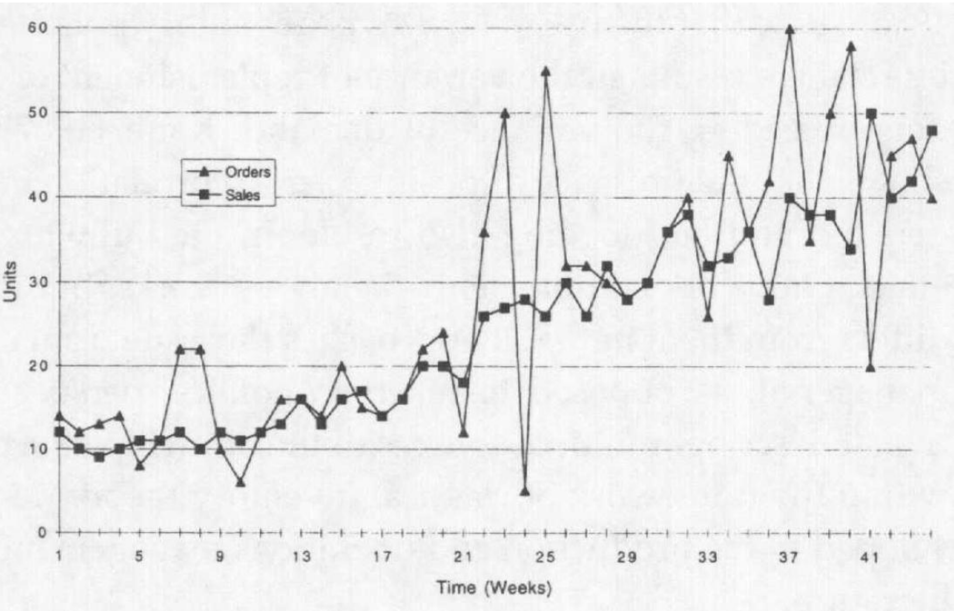
Appendix C: Bullwhip Effect

The *bullwhip effect*, also called *whiplash effect*, is a phenomenon of information distortion in a supply chain. As it is defined by Lee et al. (1997), this is the phenomenon where orders to the supplier tends to have larger variance than sales to the buyer (i.e. demand distortion), and this distortion propagates upstream in an amplified form (i.e. variance amplification). This effect is schematically illustrated at Appendix C figure 1 below.



Appendix C figure 1: Increasing order variability up the supply chain (Harrison et al., 2004)

A more life-like illustration of the phenomenon is provided at Appendix C figure 2. The figure below is based on real data.



Appendix C figure 2: Orders vs. actual sales (Lee et al., 1997)

References

HARRISON, T. P., LEE, H. L., NEALE, J. J. & WHANG, S. 2004. e-Business and Supply Chain Integration

The Practice of Supply Chain Management: Where Theory and Application Converge. Springer US.

LEE, H. L., PADMANABHAN, V. & WHANG, S. 1997. Information distortion in a supply chain: The bullwhip effect. *Management Science,* 43**,** 546-558.

Appendix D: ABC Inventory Classification

According to Arnold et al. (2008), ABC classification is based on the observation that a small number of items often dominate the result achieved in any situation. This observation is called *Pareto's law*. Applying it to inventory control, one can usually find the following pattern:

1. *A items (high value items):* The 20% of the items that account for about 80% of the total annual usage.
2. *B items (medium value items):* The 30% of the items that account for approximately 15% of the total annual usage.
3. *C items (low value items):* The 50% of the items that account for 5% of the total annual usage.

The percentage values indicated above are not absolute and may vary at different organizations. Annual usage here refers to item's cost multiplied by its annual usage.

The application of this principle is that it is often beneficial to focus on controlling the A-class items and pay least attention to C-class items, thus prioritizing time and effort to create more positive impact for the same cost.

References

ARNOLD, J. R. T., CHAPMAN, S. N. & CLIVE, L. M. 2008. *Introduction to materials management,* Upper Saddle River, N.J., Pearson Prentice Hall.