МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
Факультет кібербезпеки, комп'ютерної та програмної інженерії
Кафедра комп'ютерних систем та мереж

"ДОПУСТИТИ ДО ЗАХИСТУ"
Завідувач кафедри

_____ Жуков І.А.

"_____"_____2020 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

випускника освітнього ступеня "МАГІСТР"

спеціальності 123 «Комп'ютерна інженерія»

освітньо-професійної програми «Комп'ютерні системи та мережі»

на тему: **" Веб-додаток для керування і огляду ресурсів підприємства "**

Виконавець: _____ Мусієнко В.Е.

Керівник: _____ Іскренко Ю.Ю.

Нормоконтролер: _____ Надточій В.І.

Засвідчую, що у дипломній роботі
немає запозичень з праць інших авторів
без відповідних посилань

Київ 2020

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
Faculty of Cybersecurity, Computer and Software Engineering
Computer Systems and Networks Department

"PERMISSION TO DEFEND GRANTED"
The Head of the Department
_____ Zhukov I.A.
"_____"_____2020

MASTER'S DEGREE THESIS

(EXPLANATORY NOTE)

Specialty: 123 Computer Engineering

Educational-Professional Program: Computer Systems and Networks

Topic: **"Resource management and supervision web application"**

Completed by: _____Musiienko V.E.

Supervisor: _____ Iskrenko Yu.Yu.

Standard's Inspector: _____ Nadtochii V.I.

Kyiv 2020

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет кібербезпеки, комп'ютерної та програмної інженерії
Кафедра комп'ютерних систем та мереж
Освітній ступінь: «Магістр»
Спеціальність: 123 «Комп'ютерна інженерія»
Освітньо-професійна програма: «Комп'ютерні системи та мережі»

"ЗАТВЕРДЖУЮ"
Завідувач кафедри
_____ Жуков І.А.
"_____"_____2020 р.

ЗАВДАННЯ
на виконання дипломної роботи
Мусієнка Владислава Едуардовича
(прізвище, ім'я та по-батькові випускника в родовому відмінку)

1. Тема дипломної роботи: "Веб-додаток для керування і огляду ресурсів підприємства " затверджена наказом ректора від 25.09.2020 р. № 1793/ст

2. Термін виконання роботи (проекту): з 1 жовтня 2020 р. до 25 грудня 2020 р.

3. Вихідні дані до роботи (проекту*): система для керування і огляду ресурсів підприємства, Visual Studio, SSMS*

4. Зміст пояснювальної записки: *вступ, огляд існуючих методологій розробки систем ERP-типу, огляд технологій для побудови веб-додатку, програмного модуля системи для керування і огляду ресурсів підприємства, висновки по роботі.*

5. Перелік обов'язкового графічного (ілюстративного) матеріалу: *Матеріали представлені у вигляді презентації в Power Point.*

NATIONAL AVIATION UNIVERSITY

Faculty of Cybersecurity, Computer and Software Engineering
Department: Computer Systems and Networks
Educational Degree: "Master"
Specialty: 123 "Computer Engineering"
Educational-Professional Program: "Computer Systems and Networks"

"APPROVED BY"
The Head of the Department
_____Zhukov I.A.
"_____"_____2020 p.

Graduate Student's Degree Thesis Assignment

Musiienko Vladyslav Eduardovych

1. Thesis topic: "Resource management and supervision web application" approved by the Rector's order of 25.09.2020 p. № 1793/ст

2. Thesis to be completed between 01.10.2020 and 25.12.2020

3. Initial data for the project (thesis): *system for managing and reviewing enterprise resources, Visual Studio, SSMS*

4. The content of the explanatory note (the list of problems to be considered):

introduction, review of existing methodologies for the development of ERP-type systems, review of technologies for building a web application, software module system for management and review of enterprise resources, conclusions on the work.

5. The list of mandatory graphic materials: *Graphic materials are given in MS Power Point presentation.*

6. Календарний план-графік

№ пор.	Завдання	Термін виконання	Відмітка про виконання
1	Узгодження технічного завдання з керівником проекту	1.10.20-8.10.20	
2	Підбір та вивчення науково-технічної літератури за темою дипломного проекту	9.10.20-15.10.20	
3	Опрацювання теоретичного матеріалу	16.10.20-18.10.20	
4	Огляд існуючих технологій для розробки програмного модуля для системи	19.10.20-03.11.20	
5	Розробка програмного модуля для системи	04.11.20-12.12.20	
6	Оформлення пояснювальної записки	13.12.20-14.12.20	
7	Оформлення графічних матеріалів проекту	15.12.20-18.12.20	

7. Дата видачі завдання: “1” жовтня 2020 р.

Керівник дипломної роботи _____ Іскренко Ю.Ю.
(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання _____Мусієнко В.Е.
(підпис випускника) (П.І.Б.)

6. Timetable

#	Completion Stages of Degree Project	Stage Completion Dates	Remarks
1	Technical task coordination with the supervisor	1.10.20-8.10.20	
2	Selection and study scientific literature on the topic	9.10.20-15.10.20	
3	Work with theoretical materials	16.10.20-18.10.20	
4	Review of existing technologies for developing the software module	19.10.20-03.11.20	
5	Designing of software module	04.11.20-12.12.20	
6	Making an explanatory note	13.12.20-14.12.20	
7	Graphical materials preparation	15.12.20-18.12.20	

7. Assignment issue date: 1.10.2020

Diploma Thesis Supervisor _____Iskrenko Y.Y.
(Signature)

Assignment accepted for completion _____ Musiienko V.E.
(Signature)

ABSTRACT

The Explanatory Note to on Master's Degree Graduation Project – "Software module of the system for the interior design": 102 pages, 24 figures, 12 screenshots, 18 tables, 33 references.

Main Tasks. Learning of methodologies or company resource planning, analyzing analogs of the ERP systems, creation software affordable for small companies.

List of key words: ERP, resource managing and supervising, MRP, BOM, web-application, ASP.Net, WMS, SSMS.

The Subject of Project. Designing and investigation of ERP-type system using modern technologies and patterns of software architecture.

Practical usage. Small companies may use designed system to observe resources and manage their workflow with more efficiency.

Obtained results: As a result, the resource management system was designed by means of IDE Visual Studio using the ASP.Net technology. The system is divided into two main parts, namely the manufacturing module and the warehouse one.

With help of this system, small companies may abandon expensive analogs and have best quality for smart price. Program allows observe actual stocks in warehouses as well as at every process of manufacturing to make next orders in time to provide uninterrupted flow of production.

CONTENTS

LIST OF SYMBOLS, ABBREVEATIONS, TERMS

ERP	– Enterprise Resource Planning
HR	– Human Resources
CRM	– Customer Relationship Management
MRP	– Material Resource Planning
BOM	– Bill of Materials
MRP 2	– Manufacturing Resource Planning
CRP	– Capacity Requirement Planning
MPS	– Master Production Schedule
WMS	– Warehouse Management System
DRP	– Distribution Resource Planning
DCT	– Data Collection Terminal
DC	– Distribution Center
EF	– Entity Framework
WPF	– Windows Presentation Foundation
WCF	– Windows Communication Foundation
PHP	– Personal Home Page Tools
SQL	– Structured Query Language
DDL	– Data Definition Language
DML	– Data Manipulation Language
DCL	– Data Control Language
TCL	– Tool Command Language
API	– Application Programming Interface
DB	– Data Base

ORM	– Object-Relational-Mapping
I/O	– Input/Output
HTML	– Hypertext Markup Language
CSS	– Cascading Style Sheets
JS	– Java Script
ORM	– Object Relational Mapping
AJAX	– Asynchronous Java script and XML
XML	– Extensible Markup Language
DOM	– Document Object Model
JSON	– JavaScript Object Notation
D3	– Data-Driven Document
SVG	– Scalable Vector Graphic
MVC	– Model View Controller
DBMS	– Database Management System
DAL	– Data Access Layer
BL	– Business Layer
PL	– Presentation Layer

INTRODUCTION

With the growth of enterprises, it becomes more difficult to competently manage them. This means an optimal and balanced approach to production, in which it will give the best results. In addition, it must be competitively capable, otherwise even perfectly adjusted production will incur losses. That is, it must either be of better quality than the products of competitors, or, with the same quality, there must be a cheaper production in order to be able to have a lower price and then benefit from intercepting customers.

The task of finding the best way to do business is at the heart of all systems focused on planning and organizing enterprise resources. Such a system provides a business process processing model that covers almost all aspects in production: planning orders and deliveries, deliveries to the warehouse and shipments, movements in the warehouse itself and inventory in general, that is, up-to-date data on the availability of the necessary materials. Supply and demand planning is key to running any business because it is the starting point of all processes. Based on this information, all further production will be formed with the purchase of materials, storage, processing and dispatch to the buyer. Such systems tend to cost fabulous money. As practice shows, the program will generate income, but this will only happen in the long term.

But what should small businesses do now? For those who are just starting to develop, but who already have a complex technological process, and in addition have several workshops? They are physically unable to acquire the program, and normal control becomes simply impossible due to the desynchronization of individual production areas. Some materials were lost between the stages, nails ran out at the most inopportune moment, or something like that. Or, for example, we have somehow adjusted the work of one workshop, but how will it interact with others? The problems mentioned above are a consequence of the absence of a centralized database and coordination of actions with a phased recording of all processes occurring during production.

An ERP system consists of modules that interact with each other by sending messages and data. Some modules, such as finance, HR, or the CRM module, which initially

specializes in working with clients, are needed only for large companies or are not needed at all, since they are replaced by separate programs. For the reason that they do not function as well as specially designed software. The problem is that the availability of these modules increases the cost of the final product. For small businesses, they are generally not needed, since their work is taken over by other programs. And if we write an ERP type system taking only the most basic modules, such as a warehouse with an inventory, orders and additional orders of the necessary components, as well as a process for monitoring resources at the current stages of production, then we will get the perfect balance between the cost of software and the potential benefit that production can get. using the program to optimize the workflow and update the current amount of resources.

PART 1
METHODOLOGIES OF RESOURCE PLANNING

1.1. History of production organizing development

By means of technological progress, there were only few things that could stop humanity on the way of industrial production. For example, this process for itself became a problem because of the complexity of managing the company as a whole. The more people took part in the processes, the more difficult it was to control the quality of work performed by a single person. Accordingly, it was absolutely necessary to somehow monitor the employees' achievements with the work plan, and monitor its deviations.

At one point, the era of production workers came. The winner was the one who could be the first to occupy his niche and organize production best of all. There were a lot of workers and there must be some principle of managing a lot of people, while the difficulty lies in the fact that they must work voluntarily. Not only that, they should work well. That is, they should be added to the work, and the owner of the company in the work of his subordinates, because this forms his income. Thus, this task arose.

The first documented solution to this problem was the "Factory Code"(), which was written by English inventor and entrepreneur Richard Arkwright [1]. It spelled out the conditions under which the worker could receive a fine, as well as the daily routine that had to be fulfilled. The amount of the fine then depended on the size of the worker's offense. With the help of this code, R. Arkwright achieved much better results than his competitors due to the well-coordinated all participants in the processes, as well as uninterrupted production. This will in turn save some costs of one.

The Industrial Revolution in England was the reason why the question of a more rational distribution of labor and resources and, due to this, more efficient management of the enterprise appeared from the beginning. But the idea itself, oddly enough, originated in America. This happened for several reasons:

1) Regardless of origin and nationality, any person could achieve significant achievements being highly motivated and active;

2) Support for the developing labor market;

3) Providing the opportunity to get education for everyone.

At the moment when the first two points assumed an increase in the number of working personnel, the last point contributed to an increase in the number of people who could directly occupy managerial positions.

In this way, the next step in the development of the organization of production was the American engineer Frederick Taylor. He is considered to be the founder of the scientific organization of labor and enterprise management. In his work "The Principles of Scientific Management", using simple examples, he considered the causes of losses due to lack of sufficient productivity. As a solution, he proposed a systematic organization of labor, and not a search for some extraordinary or extravagant way [2]. In his opinion, the organization of labor is a science that has its own laws and rules. There were few principals which were proposed by Frederick Winslow Taylor:

1) Replacing work methods with methods and rules that have been formed on the basis of general experience and special studies;

2) Selection of workers and training in new working methods;

3) Differentiated wages;

4) Exemption of a specialist from the calculation and preparation of work and the transfer of these duties to special worker.

The most noteworthy was the point concerning wages. Thus, he was the first to use such a system. The system is based on maintaining the salary only if the plan is fulfilled. In case of underperformance, the amount of payment is reduced with each outstanding unit of work. In other words, a penalty was introduced. Taylor was named as “the father of scientific management”.

Tylor's system, which was formed on the basis of the above principles, has become the basis for many modern work organization systems. The object of this system was the work of a single worker. That is, there was no attempt to find a connection between the cooperation of workers in different processes and in the company in general.

G. Emerson acted exactly the opposite. In his book “The twelve principles of efficiency” he substantiated his desire to use an integrated approach to solving organizational problems in management and in general [3]. He was the person who introduced new concepts into the science of management: “productivity” and “efficiency”. Efficiency was considered as a favorable cost-benefit ratio. Twelve principles that soon began to be taken as a basis for the further development of production:

1) Accurately formed tasks for all process participators;
2) Consistency;
3) Consultation;
4) Discipline;
5) Fairness in relation to employees;
6) Accounting;
7) Dispatching;
8) Schedule;
9) Normalization of conditions;
10) Rationing of operations;
11) Written standard instructions;
12) Reward.

In 1913, Henry Ford rebuilt his production following the rules of Emerson and Taylor. He began to use conveyor belts to “carry the work to the workers, and not vice versa,” thereby saving unthinkable funds and time allotted to work. Due to the correctly configured logistics, the cost of production decreased by about four times, and the process was established so well that by 1925, 12 million cars were produced. The next page in the history of the development of production organization can quite naturally be considered the moment of the birth and development of computing systems. At that moment, it became possible to use these capacities to compensate for one moment, due to which, in the main, there were many failures and delays in the operation of an integral system called "production".

The problem was the need to plan aspects such as warehouse accounting. To, for example, avoid a situation in which some material or product is needed, but it is not. Or,

when there is an abundance of another, and because of the human factor and error, more is ordered. After all, Emerson noted in his work that accounting is vital so that the manager is provided with the most relevant information for a well-coordinated and competent organization of individual processes [3]. In addition, the disruption of the supply balance leads to the complication of the already complex and competent accounting. Then the progenitor of all modern ERP systems appeared.

1.2. MRP(0)

Material Requirements planning programs were the first programs developed for operational planning in an enterprise. [4]

The main principles of this system:

1) The order for materials is generated based on the order for the final product and production schedules;

2) Economic connectivity with the terms of the order;

3) Completion of work on time.

The system of this class was created with the aim of planning the material needs of the company as a whole. The main responsibility of such a system is to check and ensure that all the necessary parts are available.

System objectives:

1) Avoiding production downtime by adjusting the optimal number of conventional units in the warehouse;

2) Reducing storage costs;

3) Reduction of stocks of mat. - accessories.

The basis of any MRP system is a business plan. The plan is the formulation of the main points that are required to be fulfilled by the company within 2 or more years. As a rule, it requires revision to clarify or confirm the already current plan in time intervals that are equal - once every six months or once a year. In other words, this is the general vector of the company's activity, a description of the type of business. The plan offers a vision of how this or that goal will be achieved, based on forecasts. At the same time, the detailing of

such a plan is not high. The plan itself contains the formulation of market requirements and necessary goods by groups, and not the sale of individual ones.

It is also worth noting sales and operation planning, which are activities for the implementation of a strategic plan in specific and precise steps to implement it. During its creation, the following issues are resolved:

1) The number of final products that must be created in a certain period of time;

2) Supply of materials;

3) Equipment, manpower and materials;

4) Availability of resources.

Detailing level is also not high as in the strategic business plan. During design, it is necessary to consider the resource limit that the company can provide, otherwise optimization will do more harm than good.

Quantity of finished goods of each kind which is required for producing is described in master producing schedule in full manner. Sales and buys plans are taken as source as well as storages and current production. In the course of planning, a period of time is taken, which is also divided into parts that are considered a unit of measurement of time in planning. In accordance with these parts, the purchase of components is made in such a way that there are enough of them exactly as required in this period of time. This approach means saving place in warehouses and avoiding downtime when materials are scarce, which is equally waste. MRP is not associated in any way with work resources. To the same extent, the system has nothing to do with finance and accounting. Improving infrastructure and transport also have nothing to do with it.

Since the MRP is responsible for optimizing the amount of materials in the warehouse, there must be some information about what consists what. In other words, we are talking about bill of materials. It is this information that is one of the types of input information required for the operation of MRP (0). Due to the clear tracking of the amount of materials in the warehouse, the system can also perform high-quality work related to the schedule of delivery of goods to production. Based on the state of the warehouse, a purchase and production schedule are formed. This avoids downtime or excess materials in the

warehouse. In the course of work, an output is obtained in the form of an order schedule or changes to an order schedule.

Bill of materials file contains following in itself:

1) Bill of raw materials and other ones for finished good creation;

2) Structure description of finished good.

The list of materials is usually stored in databases. This is a list that consists list of materials from which finished good is collected in general. The list is formed in the form of a coded product structure tree (fig. 1.1).

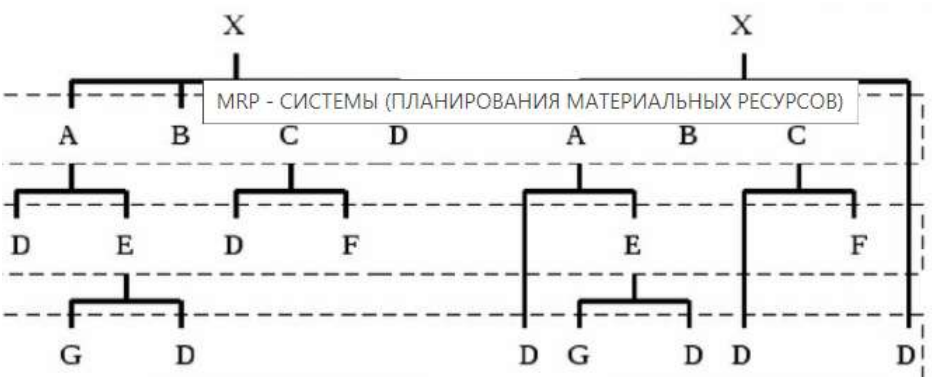


Fig. 1.1. Encoding of structure tree

Where X is the final finished product. The figure shows that the conditional product X consists of three levels. Each level is responsible for a specific stage of the assembly. Levels cannot be skipped or ordered differently because this is not part of the product specification. This encoding allows efficient storage of data in databases. Specifically, in a relational database. The encoding forms the so-called identifier, with the help of which a quick request - response is made.

Using the example of an ordinary cabinet hanging on the wall, it is possible to determine the analysis of its components with possible further encoding and entering into databases (fig. 1.2).

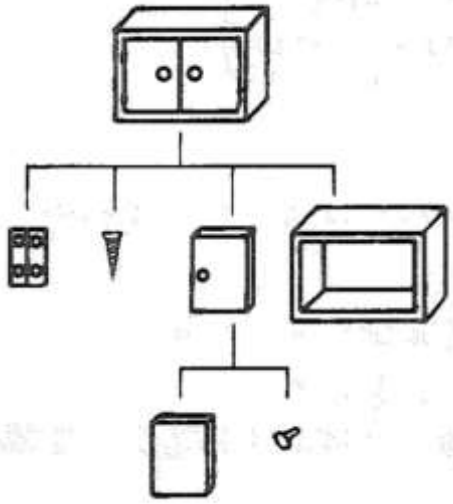


Fig. 1.2. BOM of cabinet

Thus, it is clearly visible that the cabinet consists of a pair of hinges, screws, a door and a frame. The door consists of a board and a handle. The number of parts is not indicated here only because of the schematic drawing. Or another example based on the simplest parts - bolts and nuts.

In this example, in contrast to the previous one, the process of storing information and relationships between entities is more clearly depicted. The entities here are bolts and nuts. As shown in the example, only the bolt and nut are not recorded, although they are the main “participants”. The table also indicates intermediate stages, such as the core from which the bolt will soon be machined. In the same way, entities in the table will be linked with links to what is made of and what will come out of (fig. 1.3).

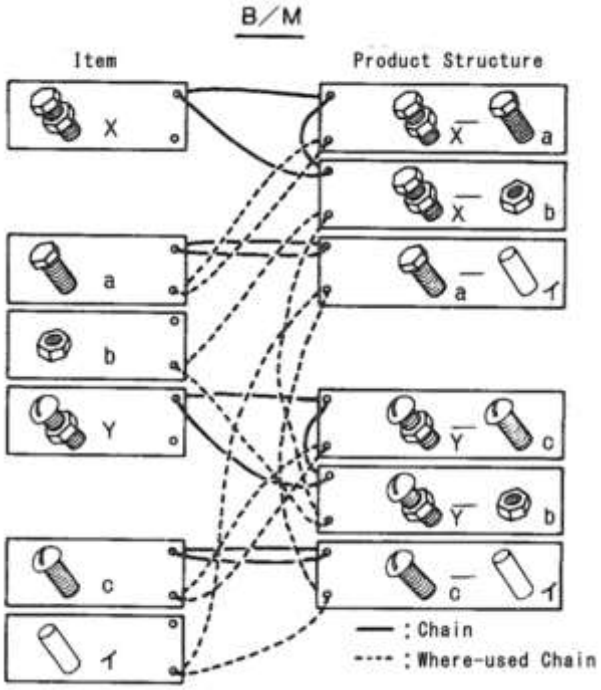


Fig. 1.3. BOM of the simplest components

Inventory status file is a document which in has detailed information about every single unit of warehouse, which includes:

1) General description (id, all parameters like size or weight);

2) Storage information which is often presented as location, amount, status, optimal and extra safes;

3) Sales and buying data like tray size, suppliers and buyers, price delivery time;

4) Production data.

As result, MRP (0) has two files:

1) Planned order schedule – document having in itself confluence about which amount of raw materials should be ordered in specific time lap;

2) Changes in planned order schedule – document having corrections for previously done schedule.

The schematic of the inputs and outputs of the MRP (0) system is shown in fig. 1.4.

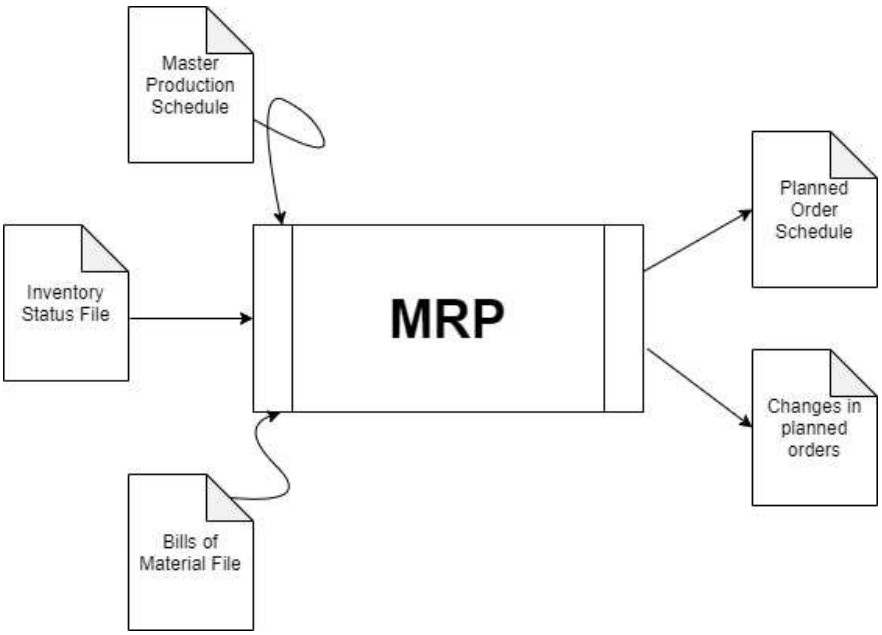


Fig. 1.4. MRP(0) inputs and outputs

1.2.1. MRP(0) module logic

All MRP functionality can be considered as module which has some steps which may repeat (fig. 1.5) [5]:

1) Calculation of the table of the required materials according to the technical specification;

2) Calculation of absolute needs which can be calculated by formula:

$$N_a = N_g - (S_c + A - S_i), \qquad (1)$$

where N_a – absolute needs; N_g – general needs; S_c – current stock; A – active orders; S_i – insurance stock.

3) Order schedule formation on base of absolute needs.

4) Analyzing of orders, done during previous planning. Comparing results, and correcting.

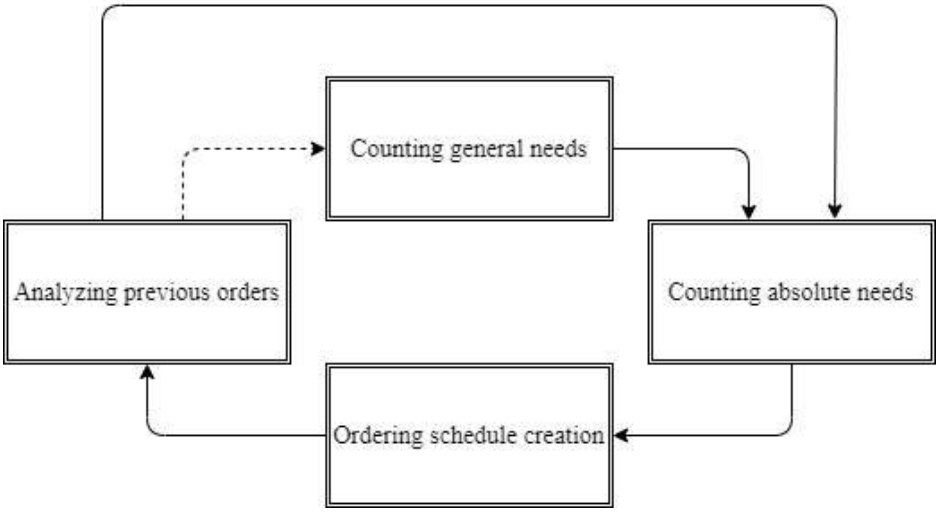


Fig. 1.5. MRP loop logic

The diagram has been simplified in a great manner, because many factors, such as numerous warehouses or supply disruptions, in order to simplify a general understanding of the process. From the picture above, you can clearly see that there is some extra branching with alternative flow. This is due to the fact that it is not always necessary to clarify the specification for the production of conventional units, but only when making changes to the production plan or modifying the final product. But the calculation of the necessary materials is always being done. This is influenced by expenses during production, receipt of previous orders at the warehouse, supply interruptions, losses during production.

1.2.2. Advantages and disadvantages of MRP systems

With the occurrence of the first programs, a number of problems associated with the complexities of managing growing enterprises were corrected. For example, the need for automatic optimization of resources in the warehouse was resolved, without downtime or, vice versa, excess, which positively affected the financial side of the issue, and also made it possible to establish uninterrupted production.

There occurred new possibility to track the exact amount of resources in the warehouse and at any time to calculate the additional required amount on the basis of which the order plan is formed.

Among the significant disadvantages should be noted the lack of a mechanism for monitoring the implementation of the plan and its instant correction. That is, in the event of a personnel error, there will be a difference between the data in the system and in the existing warehouse. The program simply does not include fixing supply failures, and to restore "balance" between the program and the real state of affairs, it will be necessary to restart the cycle, which, to put it mildly, is not economical and requires a waste of resources.

Another disadvantage is that the planning of material needs is only a small part that is necessary for effective enterprise management. The program does not consider human resource management, as well as the financial side of the issue is not recorded in any way.

1.3. MRP 2

The next generation of MRP systems was only a matter of time, because the system was far from perfect and was not flexible enough to withstand the many factors that had to be considered in production. For example, MRP viewed enterprise resources as unlimited. But this moment does not correspond to reality at all. To solve this problem, CRP was introduced, which stands for capacity requirements planning. Also, in comparison with MRP, there is planning and in monetary terms, that is, the module "Finance" has been added.

MRP 2 became the founder of the principles of detailed enterprise resource planning, which includes capacity utilization planning, production planning, supply and sales planning, production modeling, batch planning, construction and adjustment of the operational plan and tasks.

The main task of the system is to control and form the flow of raw materials and finished goods. As well as the integration of fundamental business processes: supply, warehouse updating, production, sale and distribution, order fulfillment control, finance, labor resources, material.

The result of the program is operational information about the current state of affairs in the enterprise as a whole. In the same way, you can see the details of the processes.

Schematic presentation of MRP 2 workflow is shown in fig. 1.6.

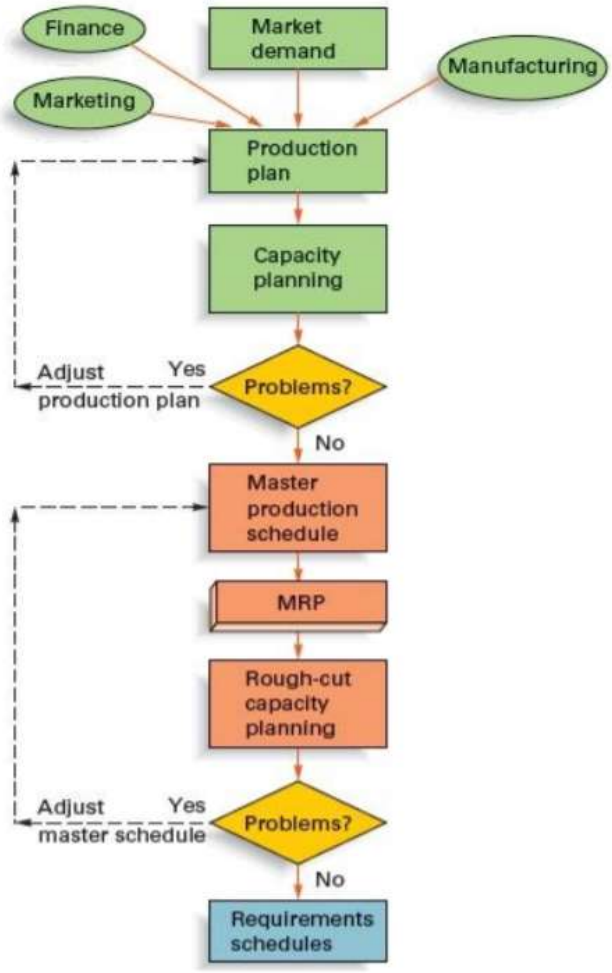


Fig. 1.6. MRP 2 workflow

According to Darryl V. Landvater, and Christopher D. Gray there are sixteen functions which MRP 2 provides [6]:

1) Specifications subsystem;

2) Material requirements planning;

3) CRP;

4) Storage managing subsystem;

5) Demand managing;

6) Sales subsystem;

7) Scheduled income orders subsystem;

8) MPS;

9) Simulation;

10) Effective production managing;

11) Finances;

12) Purchasing;

13) Quality assurance;

14) DRP;

15) Material flows control;

16) Tools supplying.

As it was considered before. MRP 2 was MRP enhancing. That is why there some functions similar for both types, like BOM and functions of MRP accordingly.

1.3.1. CRP subsystem

To solve the problem with scheduling limited resources was put on the function of capacity requirement planning. First of all, it should be noted that CRP is a system. In the course of her work, a plan is obtained that reflects the distribution of material resources at each stage of work for a certain period of work. Production capacity is the main object of this system. The determinant shows the ability to create the maximum amount of the final product for a certain period of time. The indicator is largely influenced by the technological level, working conditions and organization, the work of transport services and the level of sales organization [7].

In the fig. 1.7 it is clearly seen that, in contrast to MRP, CRP pays considerable attention to planning of production processes. Especially, the load on equipment and other labor resources. Processes here are intermediate steps between different states of good. Processes can be every action oriented on transforming material from one state to another one in direction to done product.

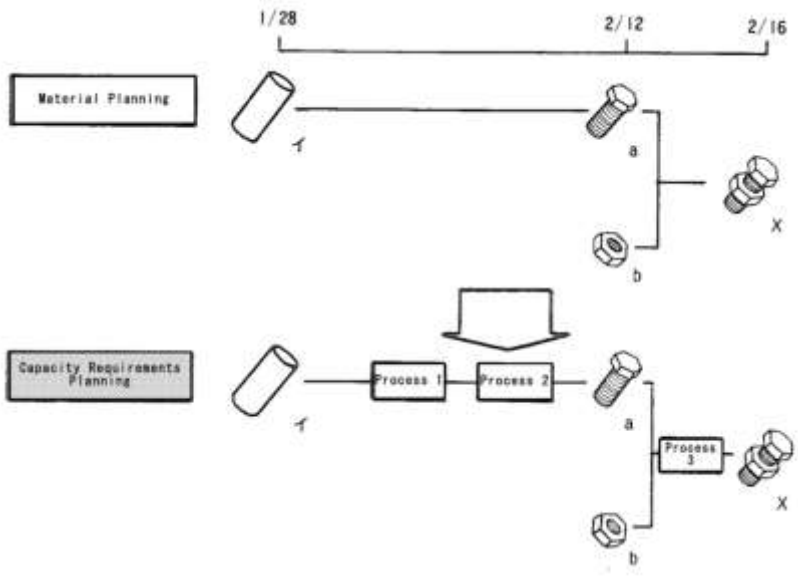


Fig. 1.7. Comparison between MRP and CRP

For a timely response to an increase in demand, the company must have a safety stock. It is described here as optional equipment. This margin will also be used in the event that an accidental loss in performance occurs.

Production capacity planning is primarily a long-term perspective in the development of the company. And, oddly enough, excess power is just as damaging, if not more so, than lack.

Production capacity is a value, the value of which tends to change. The following factors negatively affect:

1) Deterioration of the performance of machines, workbenches, etc.;

2) Complication of production by introducing more complex manufacturing processes;

3) Reduction of terms of work.

Additional power is preferably introduced after a competent assessment of the required one. Then the missing quantity is calculated between the current and required. After that, various options are assumed to solve this problem, after which the best alternative is chosen.

The pilot production program is carefully checked by the planning system, having previously made forecasts for comparison based on the available resources. Many options are being developed for performing each separate work cycle to select the optimal option.

In the established order of execution, each separately taken unit is evaluated according to the load. Based on the findings, specific measures are taken.

Capacity planning is performed after analyzing production routes, building a master production schedule (MPS) and data on work centers. Then, when calculating, the planned load of work centers is balanced after calculating the need for manufactured components.

This scheduling is done in a long-shorted perspective based on the required finished product output [8]. As input, it receives data on how much available capacity will be used. As a result, aggregate capacity plan balances output levels, capacity constraints and temporary capacity adjustment to meet demand (fig. 1.8).

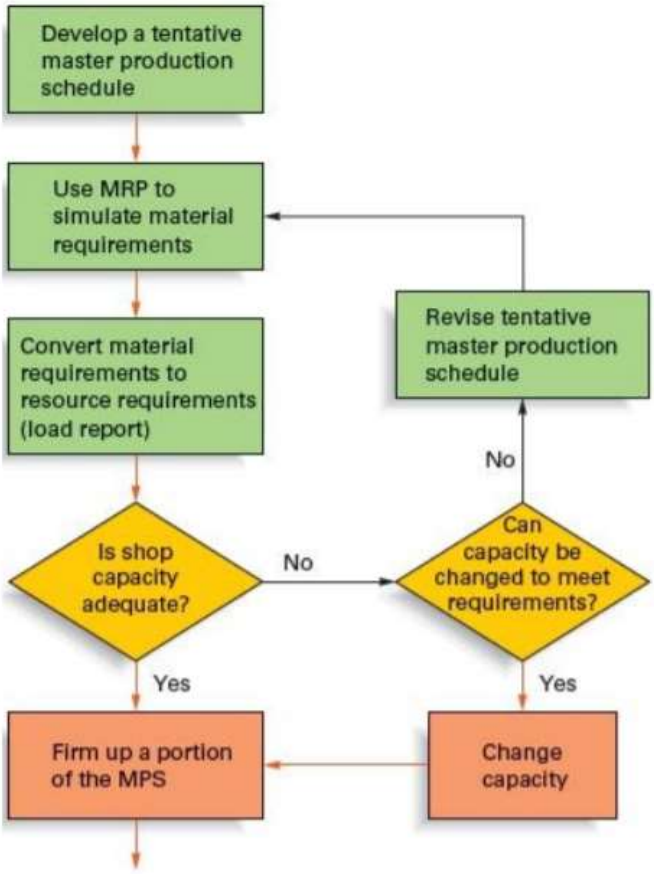


Fig. 1.8. Capacity planning process

The capacity planning process begins with MPS which is obliged to be tested in order to check whether it is possible to regulate it. The test schedule is used in the system with the intention of checking if the subsystem will generate the required data. Then the received data is verified with the actual data. As a result, the program should display the required resources for additional orders, for current tasks and already created orders.

1.3.2. WMS subsystem

Specific subsystem, which solves a number of issues related to warehouse issues of the enterprise, such as: shipping-loading of goods, storage. It optimizes the processes associated with the work of the warehouse. The primary task of the warehouse management system is to monitor the current state of resources in the warehouse, that is, balances with an exact indication of the storage location for operational access by personnel. With the growth of the enterprise, the turnover of goods increases and, accordingly, the amount of stored material in the warehouse increases. And when there are already thousands of pallets, only competent accounting can maintain uninterrupted flows of materials / goods to and from the warehouse, not to mention the inside warehouse movements [9].

The fig. 1.9 shows a fundamental difference in the operation of an enterprise with a similar system and without:

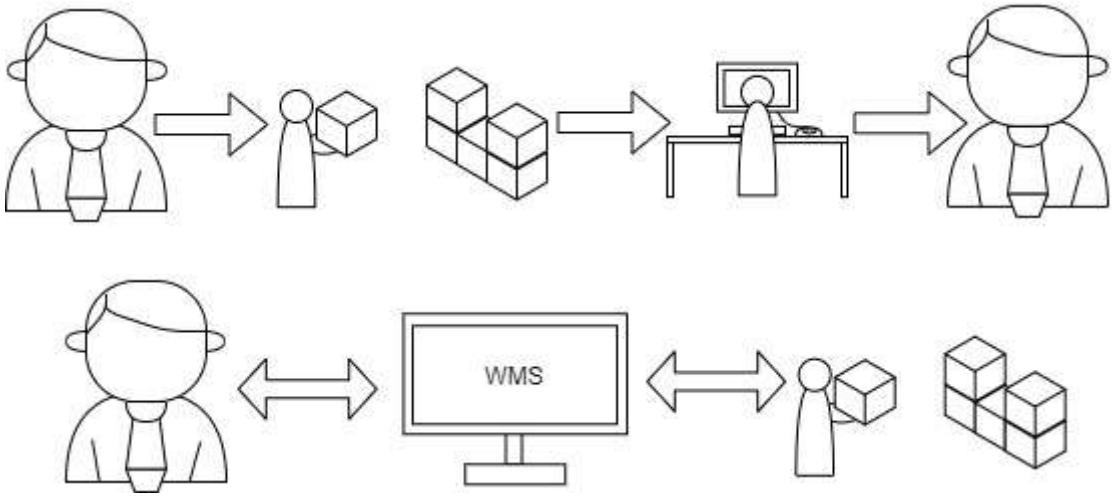


Fig. 1.9. Comparison workflow with and without WMS

The upper half of the figure schematically shows the operation of an enterprise without a system. Workflow for such situation will be:

1) The head of the warehouse forms and sets the task for the personnel;

2) Movement of goods by personnel in the warehouse;

3) Fixing changes by the operator;

4) Receipt of the report by the chief.

Workflow for enterprises using WMS:

1) The head of the warehouse forms and sets the task;

2) Setting tasks for personnel and monitoring the implementation of the system;

3) Movement of goods by personnel in the warehouse;

4) The movement is automatically displayed in the system, which allows the manager to keep track of ongoing changes.

The number of operations performed by the boss is reduced, which means that the quality of his work will increase. Now his responsibility includes specifically the work of the warehouse in general. Micromanagement is entrusted to the system.

Each such system requires data collection terminals (fig. 1.10).

Fig. 1.10. DCT Zebra MC3300 1D

The terminal is a kind of device that looks like a phone. It is necessary, first of all, to register all operations for the receipt, shipment and movement of goods. The device has a sturdy shock-resistant body, replaceable battery [9]. It has a built-in barcode scanner, thanks to which scanning takes place. Thus, information is entered, read from a drawing, which a person cannot determine visually. The advantage of scanning is that it significantly reduces the operator's chance of making mistakes by entering incorrect information. The terminals

have constant wireless communication with the server. For this reason, the warehouse must have a powerful internet distribution. The next task of WMS is to optimize business processes in the warehouse. Optimization implies a reduction in the cost of resources, both human and technology. For this, warehouse planning is used. The goods that are most often used are loaded as close as possible to the point of departure. Likewise, the most rarely used product will be placed as far as possible. When the employee picks up the right product, his route is built in such a way as to spend as little time as possible.

The main processes of a typical WMS are:

1) Identification of goods and obtaining information;

In the course of work, a barcode is read using a scanner. There is a request to the server and a response from the server is displayed on the screen in the form of a description of goods at the place of storage, supplier, order, or by the goods itself.

2) Inventory;

Allows you to check the current state of goods in the warehouse with the data in the system. Tasks of this type are created only by the boss. A pleasant plus is the fact that even one person can carry out an inventory without interrupting the work of the warehouse as a whole. In the course of the completion, the corresponding document is formed.

3) Moving and completing the goods;

In fact, these are internal movements of the goods. All movements are recorded by the system. With its help, the employee can indicate from which pallet to which one needs to transfer. And only if it is free, the transfer will be carried out.

4) Receiving the goods;

The storekeeper enters the necessary information through the terminal into the system after unloading the delivery vehicle. Then new barcodes are glued onto the new pallets that have been unloaded from the vehicle. At this stage, the condition of the cargo is checked and data on damage is entered, if any.

5) Selection of applications;

In the form of special forms, tasks are sent to the terminal for execution by employees, and I form a general queue of received tasks. The storekeeper, for example, receives information about from which box a conventional unit of goods needs to be obtained and

where to carry it. A special algorithm sorts tasks by location in such a way as to save time on moving. Types of applications:

5.1) Repackaging;

5.2) Locating;

5.3) Orders from a supplier;

5.4) Inventory;

5.5) Moving inside the warehouse;

5.6) Shipment;

5.7) Customer orders;

5.8) Order for quality control.

Thanks to this organization, the speed of work in the warehouse increases by a third, in contrast to the work of a warehouse without WMS.

6) Packing and control;

As a rule, the system has the functionality of forming and printing labels, which contains information about the employee's task and all its details. As a result of the scan, the task can have three statuses:

6.1) Shortage of goods;

6.2) Oversupply;

6.3) The order was completed correctly.

Only in the latter case, a task is created to send goods with pre-loading. In the rest, an application is created for the addition of the missing one or the transfer of excess to the original place.

7) Shipment from the warehouse.

The goods are re-checked by the number of units shipped and are automatically written off from the warehouse. In the course of work, the storekeeper verifies the barcodes with actual data and receives data from which pallet it is necessary to get the goods and in what quantity. All actions are recorded in the terminal.

1.3.3. Demand managing

Demand management is usually considered as a term from economics. Simply it describes who is your customer and what this customer wants from your system. The demand management module is rather necessary and often very useful, however usually people forget about it and get a lot of marketing problems in further system usage.

The module itself collects some demographic data about customers like some personal data (for example, the age of the customer, its sex, position on the work, or some working area, etc.), or some other data, connected to the regular life of the customer [10].

The understanding of the clients` way of thinking, their needs and wishes gives company an opportunity to define the main requirements, strategies and tools, mostly used for covering these customers` requirements. This understanding is very useful because there are a lot of possible strategies for different types of customers: those strategies, which are suitable and effective for one customer can be absolutely inappropriate for another ones. For example, some slight fluctuations of the goods price can be not effective for some reach customers at all, however for customers with very limited resources it can be a very principal point of choosing the possible partner to integrate its system into personal manufacture.

The process of defining demand is very complicated and time-consuming process, needed the involvement of some specific specialists in it, which are working with this kind of marketing staff in order to effectively integrate such module into the system.

1.3.4. Sales managing

Comparing with demand management the Sales management module is not considered as one from the economics only [11]. Sales management is defined as a term, connected to many of different spheres, like management in the sphere of sales itself (sales channels management, for example), either in the sphere of staff management, including the motivation of staff, its educational part and improving its sales skills, etc.

The following elements are usually included in the Sales system:

1) Defining the key customers for the Sales system;

2) Distribution channels;

3) Channels management;

4) Organization and strategy of the Sales system;

5) Sales system management;

6) Personal sales skills and communicational management (system of potential customers searching).

Despite of the fact that this system is very common and requested, nowadays there are the only few companies, which implemented such systems fully. Usually at least some of these features are forgotten and the only few of them are successfully implemented and integrated in real software systems.

Nowadays the require of such module if growing all the time, so more and more attempts to reorganize or integrate this module are provided by lots of companies all over the world. Many of them are trying to get on well with the current state of sales system firstly, and only then to get the understanding of what should be changed and what is going to be present in the further system versions.

The aims of the Sales system are the following:

1) The growth of the sales scales in order to make the company`s market extended;

2) To make the company`s working productivity more effective;

3) To prevent some difficulties appearance, connected to sales;

4) To define the top-priorities goods for sales;

5) To correct the sales strategy for actual market requests.

1.3.5. Scheduled income orders subsystem

For organizing the effective scheduled orders there must be integrated a subsystem of scheduled income orders [12]. Such system usually presents a set of elements, such as planning subject of orders (like vendors), object of orders (some goods or specific items), planning technology, etc.

All the predefined elements should be implemented for covering the next tasks of the subsystem:

1) Increasing of the controlled part of the market place

2) Foresight of the customer`s requirements

3) Reaching the better level of logistics

4) Providing the reconciliation of the vendors` deliveries chains actions

The main problems which the orders subsystem must resolve are the next ones:

5) Define which types of goods should be provided in the orders chains

6) How much of goods should be used in the chains of orders from the economics side

7) How these goods should be distributed among the chains and how it should be organized

8) Who will consume these goods after it will be ordered and delivered

Scheduled ordering system provides the same staff as a usual system of orders (mentioned above), but in the orders in this case can be scheduled for some period of time by means of using some additional specific technologies.

1.3.6. MPS

At the beginning of the launch of any production, you must first carefully plan everything, which is what the MPS module does. Master production schedule is a module into which all the necessary information related to production is loaded like the production time, the amount of resources spent, labor resources. Then a schedule is formed for individual products, based on the incoming data. As a result, the company receives an answer to the questions:

1) Product subject;

2) The required number of products;

3) When should the product be ready

4) Product properties.

Scheme of MPS module work is shown in fig. 1.11.

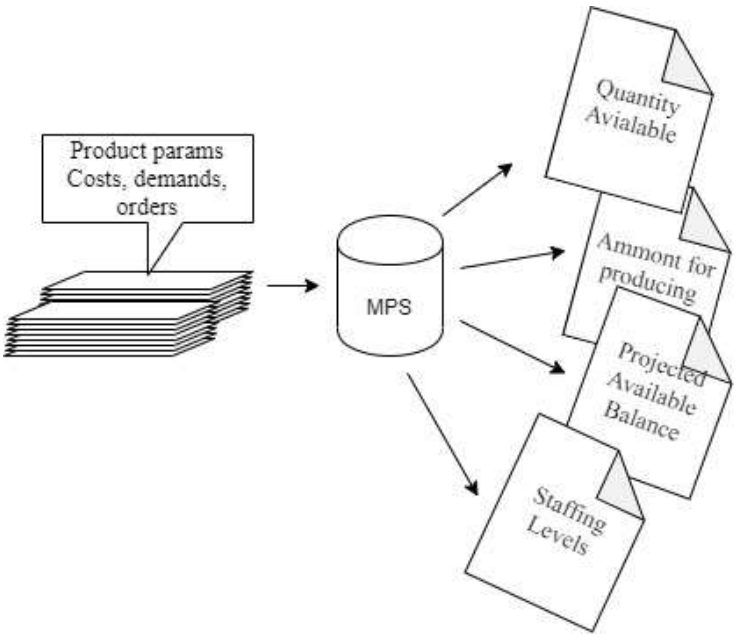


Fig. 1.11. MPS workflow

MPS is main core of planning in MRP 2.

The Master Production Schedule gives the information needed to plan and control the manufacturing operation. That is, a business plan is formed, which provides information about what needs to be produced, what materials need to be purchased for this and how much money will be needed for all this [13].

The main purpose of the MPS is to determine the production of demand for each individual product in the product group. Achieving this goal is generally divided into two parts:

1) Dividing the general plan into smaller parts. For individual production plans by product group;

2) Development of MPS.

Dividing the plan into parts is necessary for the reason that only this method gives a clear idea of how much resources are needed for a specific product, and not everything in goods in general (fig. 1.12). It is not understandable without it how many resources should be spent on each kind of good.

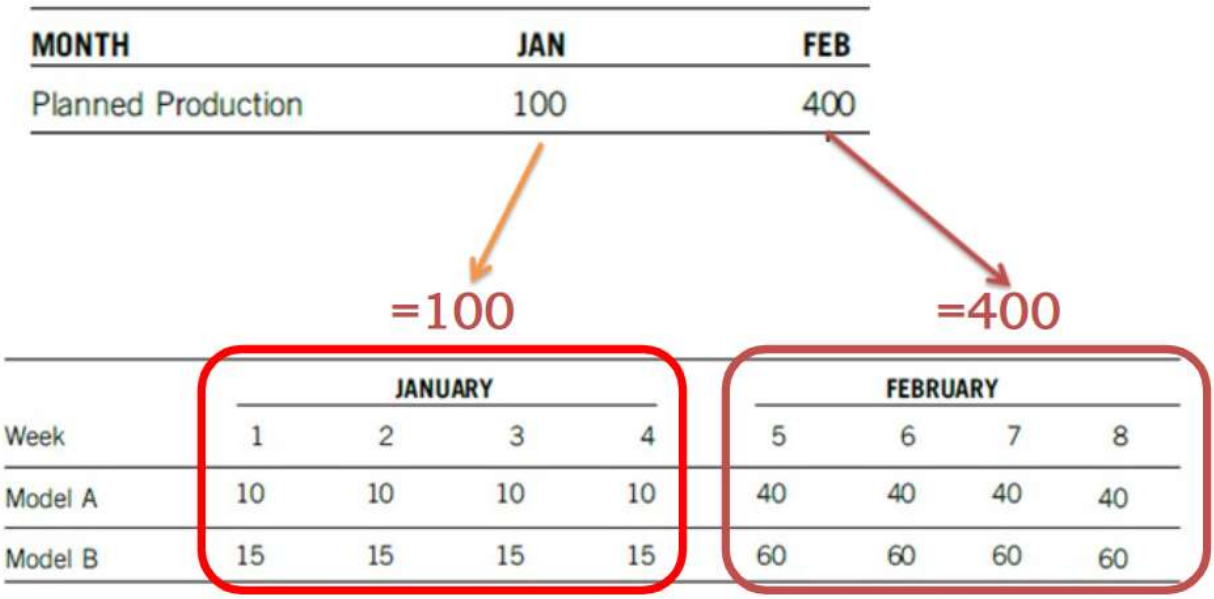


Fig. 1.12. Disaggregation of production plan

Information in this form is more detailed and is used for further distribution at the production stage. This is not an easy step, it consists of several steps. It is necessary to correctly and rationally allocate resources so that all products, in our case model A and B, can be created in parallel.

Master production schedule can be developed in various form. In most cases, it develops on the basis of demand and in some cases on the basis of raw materials. An example of such a simplified graph is given in the table 1.1.

Table 1.1

Example of MPS for a week

Products	Days							
	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total
A	2	2	2	2	2	2	2	14
B	10	-	10	-	10	-	10	40
C	15	10	5	20	-	20	8	82

1.3.7. Difference between MRP and MPS

MPS is plan for production of an individual good. Usually is connected with manufacturing with all related information about the period for which the batch must be produced, as well as the materials that must be ordered for this. MRP displays the quantity of materials and the order for assembly / production [14].

Comparative information between MRP and MPS is shown in the table 1.2.

Table 1.2

Comparison table of MRP and MPS

Subject of comparison	MRP	MPS
Plan	Dependent demand	Independent demand
Demand	Is passed down	Is direct from customer
Run	Daily	Weekly

MPS plans have direct demand. It means that demand comes from sell orders. Thus, if the product consists of two parts, and you need ten, then the plan will be an order for twenty parts. MRP plan has dependent demand that is passed down because of the need to produce an item. The MPS and MRS modules must be run separately. The question is not even so much about optimization, although this also has a positive effect on one. The question is that orders for delivery, that is, the MPS functionality, are made at a certain interval. While MRP needs to be run almost daily in order to clarify which parts need to be sent from another part of the warehouse, etc. If you imagine the finished product as a skateboard, then the skateboard will be an item of MPS and wheels or board will be an item for MRP.

1.3.8. DRP

This module is responsible for managing the process of determining the need for storage space for inventory, as well as monitoring the supply-demand ratio.

The input values for the module are:

1) Available goods for sale;

2) Time needed for creating a single unit of good from the start;

3) Customer orders;

4) Sales forecasts;

5) Safety stocks;

6) Outstanding purchase orders.

Moving goods from supplier to customer can be depicted as a supply chain. The flow of demand and the flow of supply move in opposite directions (fig. 1.13).

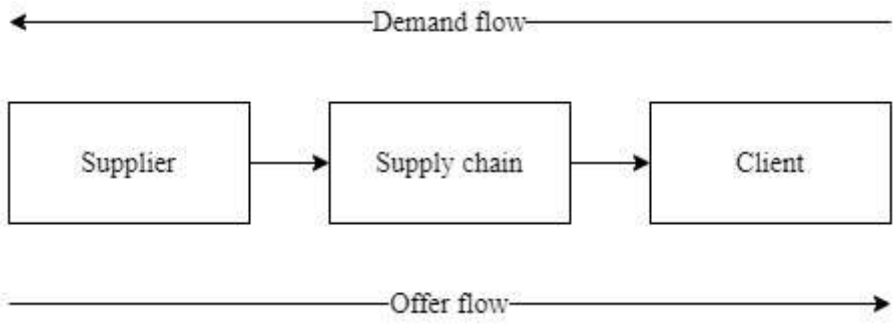


Fig. 1.13. Flows in supply chain

After entering the necessary data, the DRP module forms a model of the necessary resources to comply with the approved logistics plan, which includes the following points:

1) Transportation capacity;

2) Needed space;

3) Kind of good, quantity, place and time where it is needed;

4) Required level of production.

The module then verifies the amount of resources on hand and those that are expected to be delivered with the required amount. After that, the necessary analysis is carried out, on the conclusions of which further action is taken. At the end of the work, the generated report is sent to the logistics, production and orders department [15].

Many levels of production units are possible in the supply chain. For example, production in one area with further transportation of finished products to another area where the warehouse is located. Or such an example, when a company has one distribution point, from where further delivery to local branches comes from which they get to customers (fig. 1.14).

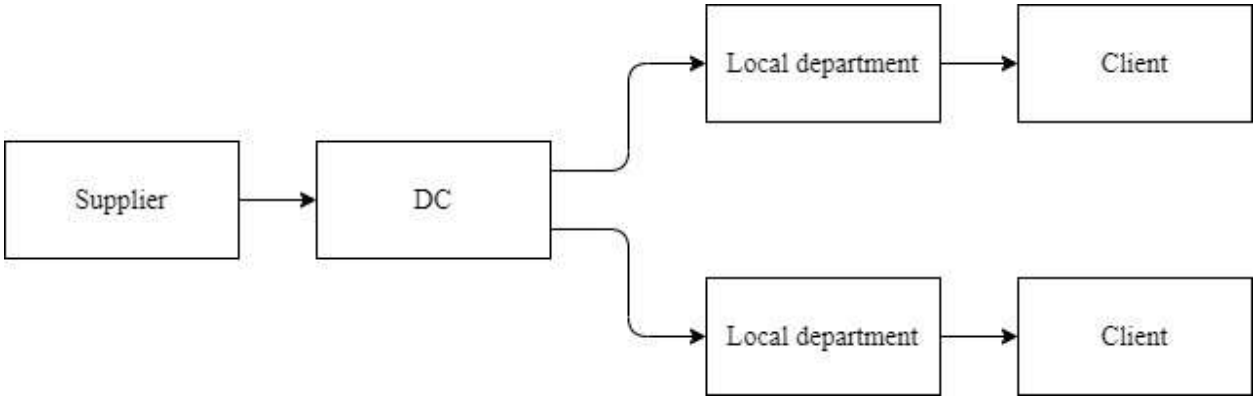


Fig. 1.14. Example of supply chain

The main questions that are posed to the DRP:

1) What you need to get from other departments;

2) What should be sent to other departments;

3) What can be sent.

Unlike MRP, where it is enough to know what needs to be sent and how much, in DRP an additional factor is the presence of branching of production, which adds another question “where” [15]. The first question is answered by the demand for material that needs to be delivered from another department. The second is the demand for the product that is being produced. On the third - the availability of supply in the form of materials plus transport.

1.4. ERP

Generally speaking, ERP which stands for Enterprise Resource Planning is the strategy of the whole organization to manage all the processes that occur. A remarkable property is that it can consist of modules that can complement the already existing functionality [16].

The introduction of ERP systems into the work of an enterprise is a very difficult and lengthy process. A complete analysis and revision of all business processes of the enterprise is required. In addition, they all have to be debugged in order to have some kind of system. This factor is verified by independent research by specially hired specialist consultants. The result will inform whether it is potentially possible to introduce a system for the management and organization of production, or whether it is first necessary to carry out corrective work with problematic business processes.

Thus, ERP-system is software that aims to manage production according to planning. The program usually consists of different modules, which are responsible for:

1) Establishment of supplies, their communication;
2) Scheduling and planning;
3) The module is responsible for commerce;
4) End product data management;
5) Resource planning;
6) Sales.

System operation is a continuous process aimed at continuous monitoring of all processes, reporting and adjustment according to multiple criteria.

1.4.1. Reasons for implementing ERP

ERP systems greatly affect all types of businesses in size. They can influence competitors in the same way. Provided that the implementation can give an advantage, the competitor is obliged to react quickly and also start implementing such a system, otherwise it risks simply being kicked out of the market [16].

The program allows the company to be more flexible, as the information there spreads quickly enough. That is, the company can quickly process incoming information and respond to changes. Due to this, there is a faster regulation and balancing of processes in the enterprise, since all operations take place in real time.

In fact, an ERP system is wholly and entirely composed of the so-called "best practices", that is, the best ways to implement business processes. The main questions that should be asked when doing business competently:

1) What business processes provide advantages in relation to competitors;

2) What implementations will allow us to take a leading position in the competition;

3) What is unique in the business processes of our company, which makes us better than our competitors;

4) The cost of spending on improving the business process to close the gap if competitors are leading, or to widen it, to maintain the leading positions based on the answers received as a result of the analysis of the questions posed, the further policy of the enterprise and the bias towards the development of vulnerabilities are formed.

Main criteria's which company owners are looking for are shown in fig. 1.15 [16].

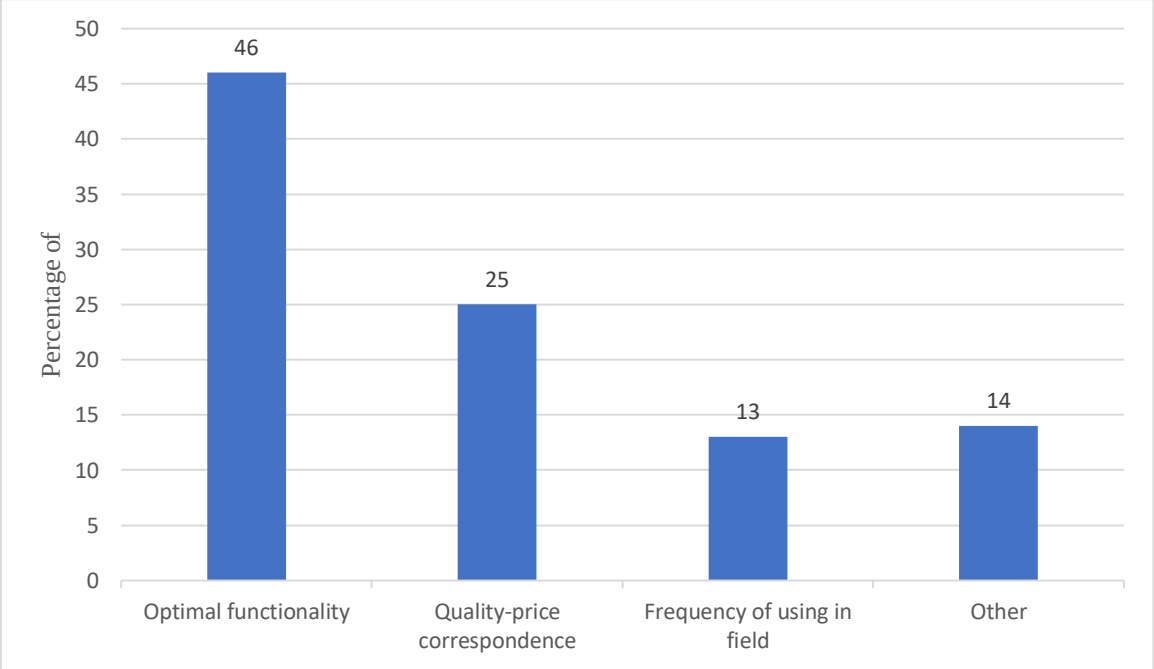


Fig. 1.15. ERP selection criteria

ERP is perfect solution for companies which have specific problems like:

1) Difficulties in planning with great accuracy;

2) Lack in operative stock information;

3) Nonefficient production process;

4) Absence of time estimation and failure to fulfill orders on time as a result;

5) Untimely equipment failure;

6) Actual expenditures exceed planned.

Typically, ERP is a combination of best practices that economists and technologists have come to after many years of studying the processes that are required in production.

1.4.2. Risks of ERP type systems

Of course, the implementation of ERP systems is initially aimed at the development of an enterprise and its individual business processes. But one should not exclude the fact that, despite the positive aspects of this process, it may be accompanied by some situations in which not a positive effect is achieved, but on the contrary.

Risk groups can be conditionally divided as follows:

1) Consultants (those who help to implement the system);

2) The owner of the company;

3) An employee of the company;

4) Management personnel.

One of the most difficult tasks for managers is deciding on the type of ERP system, selecting consultants of the appropriate level. They are primarily interested in the successful completion of tasks in a narrow current aspect, and not in the picture as a whole, thus forming this very picture. The qualifications of managing specialists must grow, that is, the skills of using computer systems must be mastered along with the theoretical basis of control using new methods. This is necessary to avoid a situation in which a top manager loses the ability to effectively or even completely manage production processes. This happens due to the replacement of the organizational work of a person with the ERP system, combined with the inability to analyze and solve the optimization of employee labor.

The owner is primarily at risk from a financial point of view. Since investments in numerous changes to the organization of the company's work will be in any case, but further cost optimization and increased productivity is not a fact.

For ordinary ERP workers, the system does not become a release from the performance of current duties, but on the contrary, it is additional work. In this case, it happens that an employee may simply not have time to complete part of the work that was

entrusted to him. For this reason, employees are sometimes freed from part of the workload, or compensated in the form of a salary increase.

According to Zeng Y., risks may be divided in following groups [17]:

1) Organizational - the structure and business processes will be changed in such a way that all the benefits will be equalized with the problems that arise during the implementation of the system;

2) Operating - the operation of the system leads to an increase in the cost of maintaining one;

3) Behavioral - inappropriate behavior of the participants;

4) Management;

5) Technological;

6) Human.

There are also many other risks that can be caused by the customer or the contractor. Thus, the inconsistency of tasks between the contractor and the customer can lead to the final stop of the project or freeze or increase in cost, which is also undesirable. Prevention of such a problem can be the premature approval of the specification.

The owner can simply lose interest in the project and stop financing, which will lead to the termination of financing and the closure of the project. To avoid it, you can monitor the progress of the project and inform the owner of the results. Or there may be a completely different situation - when the project participants change from the customer's side. The best thing that can happen with this is freezing and increasing the cost.

Provided that there is no qualified specialist for individual business processes taken, the solution in the project may not meet expectations, that is, be significantly lower for the reason that it will not be able to satisfy all the needs for high-quality business management. The project will be completed simply after the fact and the result that was initially achieved by implementing the system will not be achieved.

As with any other information technology project, there are typical risks:

1) Commercial risks;

It has to do with how competitive the technology is compared to the rest of the ones. Also, the evaluation criteria are relevance, which affects the availability and support of the software on which the project is written.

2) Failure on time;

Difficulties which may occur when business - processes are not accurately planned as well as project timing estimation.

3) Rejection by employees;

A change in the workflow can be negatively perceived by workers. Despite the fact that the innovations for the most part bring a positive effect, the very principle of transition to something new can be perceived negatively.

4) Integration;

Basically, this is always a high risk, because there is integration with the existing infrastructure, after which serious errors can occur. It will also be necessary to retrain staff, in addition, it is impossible to avoid additional costs due to the stoppage of the enterprise to implement new changes.

5) Technical.

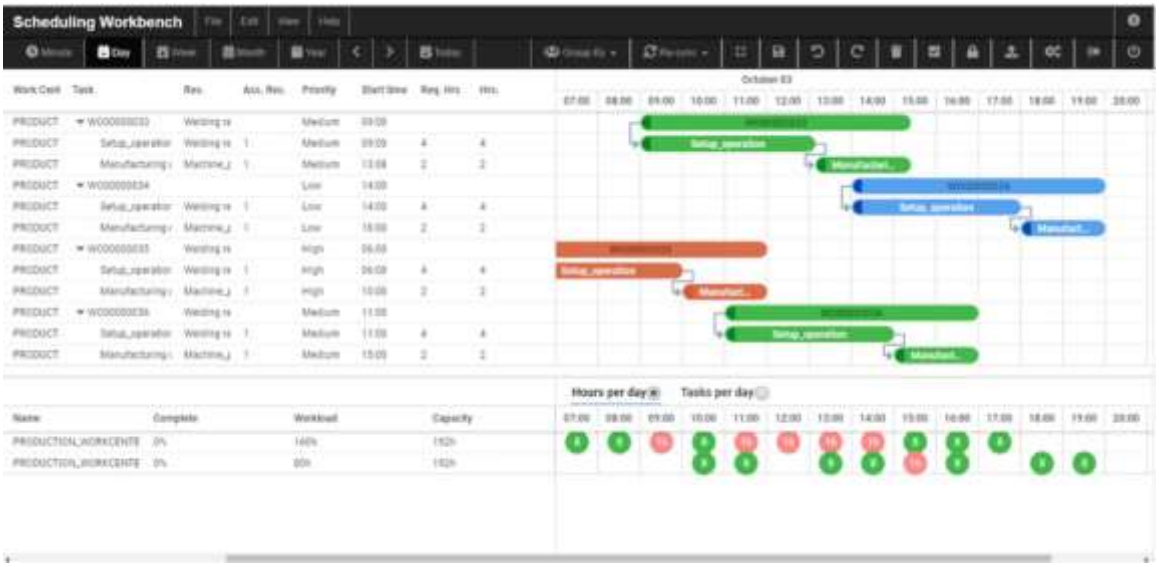
This type of risk includes everything related to technology. This can be equipment failure, malfunctions due to excessive wear.

1.5. Analogs of the program

There are lots of different companies that offer their ERP solutions. Most of them provide basic ERP functionality. Each company strives to sell exactly its product. Therefore, there is a real fight for customers in the ERP software market. One of the best indicators on the market is ease of use and versatility. It is believed that the better the product, the less changes need to be made in order to make it fit the final requirements of the consumer.

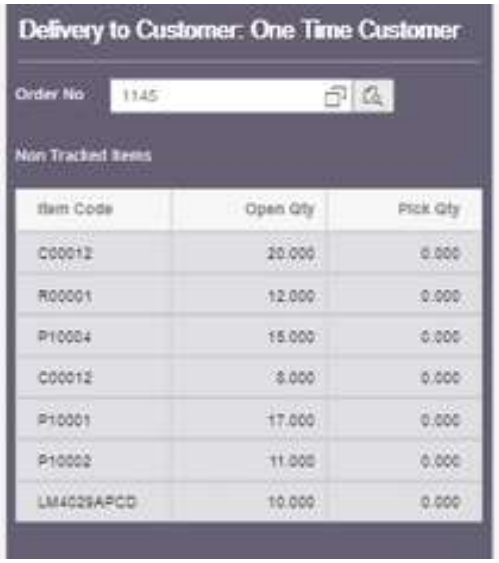
1.5.1. OptiProERP

An American company that has been offering quality software for over 20 years. Are considered experts in the field manufacturing and distribution solutions. Provide great support for their customers. Software is intuitive and does not need great experience in some fields to be used [18]. All operations may be easily observed by means of specially designed screen (screenshot. 1.1).



Screenshot.1.1. Screen of OptiPro`s workbench

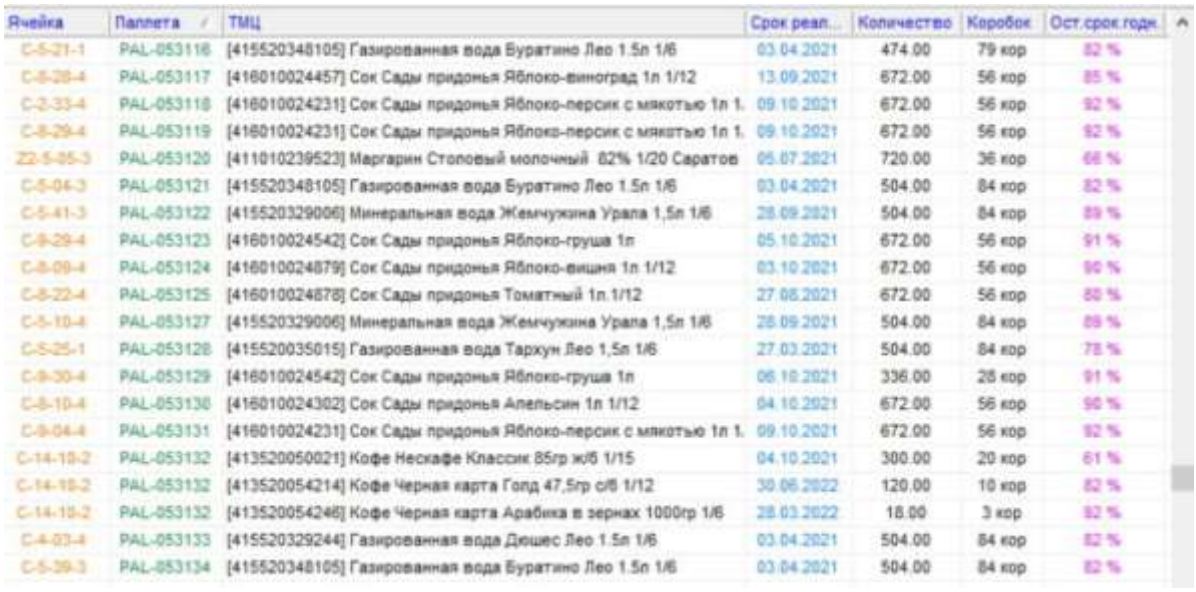
Main fields of this software are manufacturing and distribution (screenshot 1.2).



Screenshot.1.2. Delivery screen

1.5.2. Buhta

A company whose main product is a WMS system. It provides software for managing all business processes in the warehouse, as well as the efficient operation of the warehouse complex as a whole [19]. The system has a barcoding and reading mechanism. The server with the program is able to provide the current state of stock balances at any time (screenshot 1.3).



Ячейка	Паллета	ТМЦ	Срок реал...	Количество	Коробок	Ост.срок годн.
C-5-21-1	PAL-053116	[415520348105] Газированная вода Буратино Лео 1.5л 1/6	03.04.2021	474.00	79 кор	82 %
C-5-28-4	PAL-053117	[416010024457] Сок Сады придонья Яблоко-виноград 1л 1/12	13.09.2021	672.00	56 кор	85 %
C-2-33-4	PAL-053118	[416010024231] Сок Сады придонья Яблоко-персик с мякотью 1л 1.	09.10.2021	672.00	56 кор	92 %
C-8-29-4	PAL-053119	[416010024231] Сок Сады придонья Яблоко-персик с мякотью 1л 1.	09.10.2021	672.00	56 кор	92 %
Z2-5-05-3	PAL-053120	[411010239523] Маргарин Столовый молочный 82% 1/20 Саратов	05.07.2021	720.00	36 кор	66 %
C-5-04-3	PAL-053121	[415520348105] Газированная вода Буратино Лео 1.5л 1/6	03.04.2021	504.00	84 кор	82 %
C-5-41-3	PAL-053122	[415520329006] Минеральная вода Жемчужина Урала 1,5л 1/6	28.09.2021	504.00	84 кор	89 %
C-8-29-4	PAL-053123	[416010024542] Сок Сады придонья Яблоко-груша 1л	05.10.2021	672.00	56 кор	91 %
C-8-09-4	PAL-053124	[416010024879] Сок Сады придонья Яблоко-вишня 1л 1/12	03.10.2021	672.00	56 кор	90 %
C-8-22-4	PAL-053125	[416010024878] Сок Сады придонья Томатный 1л.1/12	27.08.2021	672.00	56 кор	80 %
C-5-10-4	PAL-053127	[415520329006] Минеральная вода Жемчужина Урала 1,5л 1/6	28.09.2021	504.00	84 кор	89 %
C-5-25-1	PAL-053128	[415520035015] Газированная вода Тархун Лео 1,5л 1/6	27.03.2021	504.00	84 кор	78 %
C-8-30-4	PAL-053129	[416010024542] Сок Сады придонья Яблоко-груша 1л	05.10.2021	336.00	28 кор	91 %
C-8-10-4	PAL-053130	[416010024302] Сок Сады придонья Апельсин 1л 1/12	04.10.2021	672.00	56 кор	90 %
C-9-04-4	PAL-053131	[416010024231] Сок Сады придонья Яблоко-персик с мякотью 1л 1.	09.10.2021	672.00	56 кор	92 %
C-14-15-2	PAL-053132	[413520050021] Кофе Нескафе Классик 85гр ж/б 1/15	04.10.2021	300.00	20 кор	61 %
C-14-15-2	PAL-053132	[413520054214] Кофе Черная карта Голд 47,5гр с/б 1/12	30.06.2022	120.00	10 кор	82 %
C-14-15-2	PAL-053132	[413520054246] Кофе Черная карта Арабика в зернах 1000гр 1/6	28.03.2022	18.00	3 кор	82 %
C-4-03-4	PAL-053133	[415520329244] Газированная вода Дюшес Лео 1.5л 1/6	03.04.2021	504.00	84 кор	82 %
C-5-39-3	PAL-053134	[415520348105] Газированная вода Буратино Лео 1.5л 1/6	03.04.2021	504.00	84 кор	82 %

Screenshot.1.3. Inventory screen of Buchta:WMS

The main directions of warehouses that are supported by this program:

1) Manufacturing;

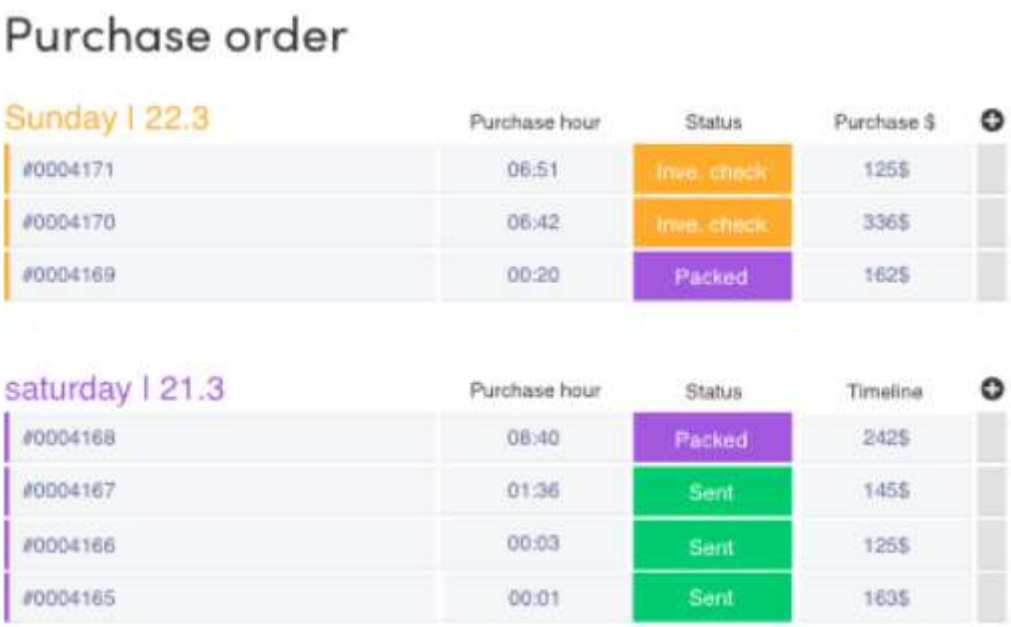
2) Wholesale and retail trade;

3) Distribution;

4) Pharmaceuticals.

1.5.3. Monday

Production management is what Monday software does the best. It is specially designed for. Way from manufacturing to purchasing and delivering will be tracked to observe progress at every moment of time (screenshot 1.4).



Screenshot.1.4. Purchase order screen in Monday ERP

Suits great for small and medium size business wanting control every step to be able react fast. It is also worth noting that in this program it is very easy to track the work of individual teams with their latest tasks. Software is written in such a way that it is easily extensible and consists of modules. Added the ability to integrate an environment with many applications from Microsoft and not only [20]. Basically, the program offers management functionality to track the current execution of tasks and assign new ones. Also linking to corporate mail and other collaborating teams.

1.5.4. Clobbi

Clobbi`s product is a result of collaborations of different developers among all Europe. First service was created in 2014 and since than company has been growing rapidly. And now software provides:

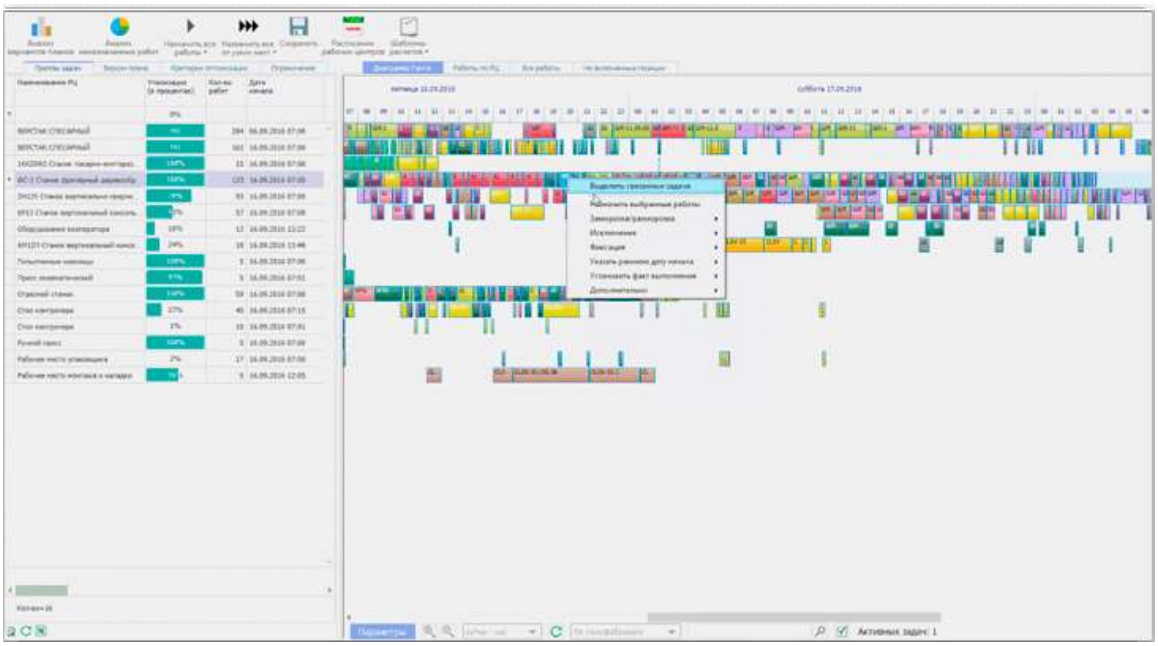
1) Sales and buying subsystems;

2) Financial module;

3) HR;

4) Management.

Program allows to observe all processes at one screen simultaneously which gives real understanding whether work will be done in time or not (screenshot 1.5).



Screenshot 1.5. Manufacturing planning screen

What distinguishes this software among others - it has 3d workshop live (screenshot 1.6). On this window, you can track the current status and task of each individual equipment. It is possible to quickly and easily transfer a product model from the modeling program to Clobbi, which significantly reduces the time spent on filling out enterprise directories [21].

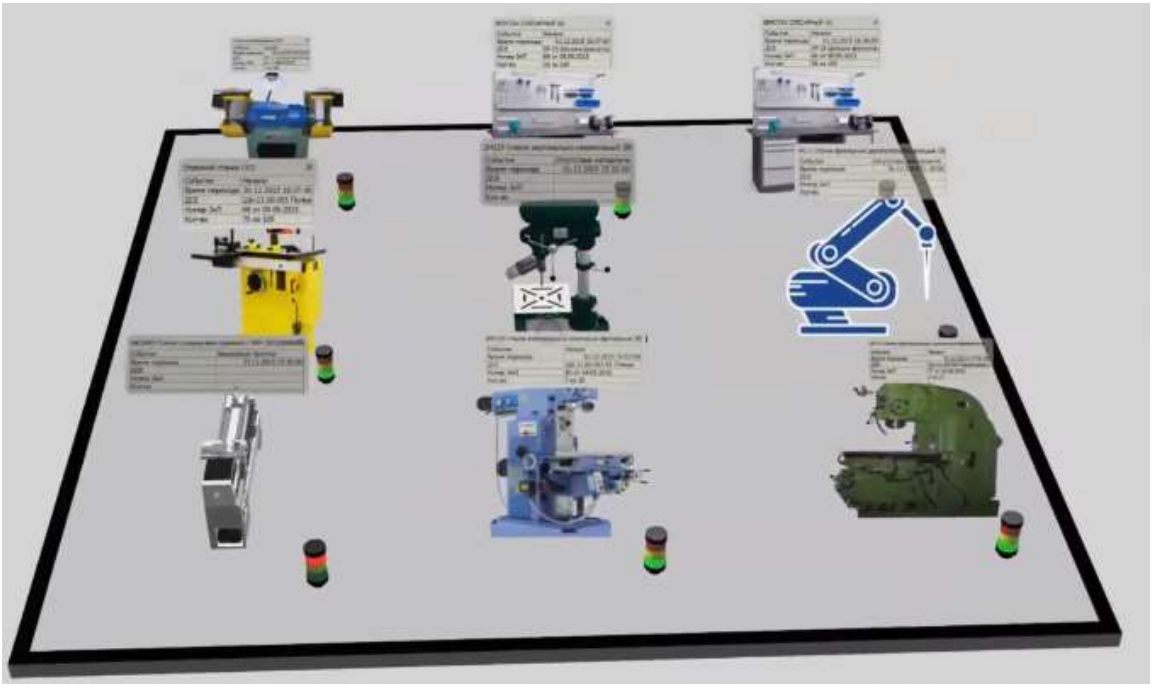
Clobbi software is based on some principles and standards necessary for full-fledged production management:

1) Theory of Constraints;

2) Advanced planning and scheduling - concept of synchronous production planning;

3) Scheduling theory - scheduling mechanism;

4) MRP.



Screenshot. 1.6. 3d workshop in Clobbi software

1.5.5. WorkWise

This company provides a CRM module that includes exceptional customer service that increases productivity through mobile CRM usage. Thanks to CRM, managers make fewer mistakes, which means they sell more and more often: Speeding up the work of managers means that they will be able to devote more time to the actual sales, and therefore, increase the volume of transactions. Sales growth and an increase in the average check give an increase in profits. Higher profits enable more resources to be invested in business growth. Business development gives even more profit, as well as the opportunity for the leader to become the head of a large successful company. The main statistics window is shown in the screenshot 1.7 [22].

Screenshot 1.7. Dashboard with statistics

The system also has an Inventory module for tracking product movements. It also keeps track of batches and batch production.

Conclusions of the first part

In this part main methodologies of resource planning were observed. The step-by-step development of MRP-type systems, as well as individual modules and their interaction with each other, such as WMS - for inventory, tracking the movement of goods in the warehouse, shipment and loading of goods, to obtain general information about the goods in the warehouse, or MPS, were considered. which gives the information needed to plan and control the manufacturing operation.

Also, in this section, some analogs of programs that provide their ERP systems were considered, their features and key functionality for a particular company were considered.

PART 2
WEB STACK TECHNOLOGIES

With the development of web technologies, all Internet products are becoming more complex and functional. A growing niche is occupied by web applications displacing desktop versions. You can hardly see a person buying a CD now. Internet access is the main issue a developer faces when creating a web application.

Since the goal of this diploma was to create a web application, this theoretical part will cover the technology stack required to create one.

First of all, when you visit the site, you see the components that make up the site: menus, navigation, perhaps some input fields. That is, the frontend is everything that is rendered while working in the browser. It can be buttons, i / o fields, anything that is felt by a person. Backend is a complex system that allows any web application to function. This is all the computational logic, in other words, the entire software and hardware part of the service. The backend implements all the functionality to which the user does not have direct access, for example: storing and processing data, integrating the payment system, sending letters, loading page content. The user uses the backend functionality through the interfaces.

The backend is responsible for:

1) The performance of the web application logic;

2) API;

3) Debugging the application as a whole and individual component;

4) Integration with various services;

5) Working with the database.

Typically, in large web applications, it is necessary to build the system in such a way that it can handle heavy loads. Micro service architecture encouraged, containerization. It is necessary to organize a monitoring system.

2.1. C# / .NET and ASP.NET

Nowadays C# is one of the most well-known programming languages all over the world. It is powerful, fast-developing and extremely demanded programming language in the information technology sphere. At the current moment C# can be used in the vast amount of different project types. Using it there can be created any type of applications: desktop ones (WPF, WCF), mobile applications (Xamarin), web applications, such as web-services, web-portals, etc.

C# is not a young language (it was initially developed at the year of 2001 by a team from Microsoft) and since that time it has being developed till nowadays. The first working version of C# language was seen by the world in the 2002 with the with Microsoft Visual Studio .NET. The last stable version of the C# is C# 9.0 with the .NET 5 platform [23].

Talking about C# it is usually about the stack of .NET technologies, having used C# as a basis language. In the following diploma project there were used some of .NET technologies, specifically ASP.NET and Entity Framework (EF). It is necessary to note, that .NET platform is suitable not only for C# language, but for some others as well (like VB (Visual Basic.NET, Jscript, PHP, Perl, etc.)).

ASP.NET – an abbreviation for Active Server Pages for .NET platform – is a Microsoft framework, defining a structure for the web project [23]. ASP.NET has a couple of features, that differ it from the other platforms:

1) Compiled code executes much faster because of the error catching mechanism, which catches the most of the errors at the implementing stage;

2) It has executable set of management elements and class libraries, that speeds up the project implementation process;

3) The opportunity to cash all page, its parts or some specific data, used on the page;

4) The opportunity to divide the BE and FE (back-end and front-end) parts on the different files. Also, it is possible to define the most often used templates of the user`s elements, like site`s menus, some layouts, etc.;

5) It supports AJAX technology as well;

6) It has different Views (like GridView), that helps to integrate CRUD (Create-Read-Update-Delete) operations easily;

7) It has integrated MVC pattern (ASP.NET MVC Framework). In the current project there was used exactly this type of project;

Despite of the fact that .NET was initially designed for Microsoft Windows operational system, by now it can also be used in other systems as well with a new .NET Core platform.

ASP.NET – is a platform, which provides the necessary functionality for creating web-sites and web-applications. Using ASP.NET the code can be written in different language, but in this project the C# was used. Since 2019 .NET Framework is not being developed more. After that many versions of the platform .NET Core appeared.

.NET Core is an analogue of cross-platform .NET platform. .NET Core is a priceless open-source platform for creating applications of different types as the following:

1) Web-applications, APIs and microservices;

2) Serverless features stored in clouds;

3) Mobile applications;

4) Forms, WPF, etc.;

5) Machine learning;

6) Console Applications;

7) Windows services.

2.2. SQL

SQL stands for Structured Query Language. It is a database management language for relational databases.

SQL has four distinct parts:

1) Data Definition Language (DDL) is used to define the data structures stored in the database. DDL statements allow you to create, modify and delete individual objects in the database. The allowed object types depend on the RDBMS being used and typically include

databases, users, tables, and a number of smaller supporting objects such as roles and indexes.

2) Data Manipulation Language (DML) is used to retrieve and modify data in a database. DML statements allow you to retrieve, insert, modify, and delete data in tables. Sometimes data retrieval select statements are not considered part of the DML because they do not change the state of the data. All DML statements are declarative.

3) Data Access Definition Language (DCL) is used to control access to data in a database. DCL statements apply to privileges and allow you to grant and revoke rights to apply specific DDL and DML statements to specific database objects.

4) The Transaction Management Language (TCL) is used to control the processing of transactions in the database. Typically, TCL statements include commit to commit changes made during the transaction, rollback to undo them, and save point to split the transaction into smaller chunks [24].

2.3. Entity Framework 6

Entity Framework is an ORM, which is usually used with .NET platform and C# language itself. First of all, it is necessary to define the term ORM. ORM means Object-Relational-Mapping, that means a technology, used for mapping entities in the database with entities in code. In another words, ORM is a layer between the database and the code. It is used for processing some data in the database and for providing some operations on it.

Objects in the Entity Framework ORM are represented in the form of tables with some inner limitations and inner-connections between these tables. Connections between tables can be presented in different forms, where some of which are provided by Entity Framework. These connection types are:

1) One-to-One (provided by Entity Framework);

2) One-to-Many (provided by Entity Framework);

3) Many-to-Many (is provided by using the additional table, so then it is much more difficult to use Code-First approach in order to generate such tables using Entity Framework).

Talking about approaches of generating a database by means of using Entity Framework, we can consider the 3 ones [25]:

1) Code-First; The code is written firstly in the IDE, then the package with Entity Framework is installed and by using it the database with all inner tables are created on the server, no matter whether this server is remote or local.

2) Model-First; The model is implemented firstly (considering that the database already exists). This model is uploaded to the previously downloaded Entity Framework, and using it a Model.edmx file (model in the database) is automatically generated.

3) Database-First. The database is created on the server part firstly. In the MSSQL the server has been created by using the SSMS IDE (SQL Server Management Studio Integrated Development Environment) with SQL / T-SQL.

The current project has been created using Database-First approach in order to avoid all the problems, connected to the generating Many-to-Many connection between entities in the database.

Also, it is necessary to note that the Entity Framework represents much higher level of abstraction, comparing with well-known ADO.NET. By sacrificing with some connection speed and speed of working with data in the database it provides much more comfortable “user interface” and ready “packaged solutions”. That means, that development process is much faster than if developer used ADO.NET transactions instead of Entity Framework.

The tool, which is used by Entity Framework for successful reach to the data is called LINQ. LINQ – Language Integrated Query – is a query language to the data source. It can work with any object, which implements the IEnumerable interface, represents DataSet from the database (like in case with Entity Framework or any other ORM technologies, working with relational database) or even XML document. Talking about Entity Framework LINQ is used as LINQ to Entities (however we can use LINQ to SQL, avoiding working staff connected to Entity Framework itself).

2.4. HTML & CSS

Hypertext Markup Language is a markup language that the browser interprets as the user sees it on the screen. The content of the page is encapsulated into many lists, containers, tables, but in the end the user does not see even half of it, although it forms the structure of the page. Unlike a file with the .doc extension, even if the html content is character to character, repeated with the document, the html size will be many times smaller. This happens because a text file is best suited for transfer

Opening tag: Consists of the element's name (in this case, "p"), enclosed in opening and closing angle brackets. An opening tag indicates where an element begins or begins to act, in this case, where a paragraph begins.

Closing tag: This is the same as the opening tag, except that it includes a forward slash in front of the element name. The closing element indicates where the element ends, in this case, where the paragraph ends. Missing an end tag is one of the most common beginner mistakes and can lead to strange results.

Content: This is the content of the element, which in this case is just text.

Element: The start tag, end tag, and content together make up an element.

Element: The start tag, end tag, and content together make up an element.

Sctructure of a simple tag is shown in fig. 2.1.

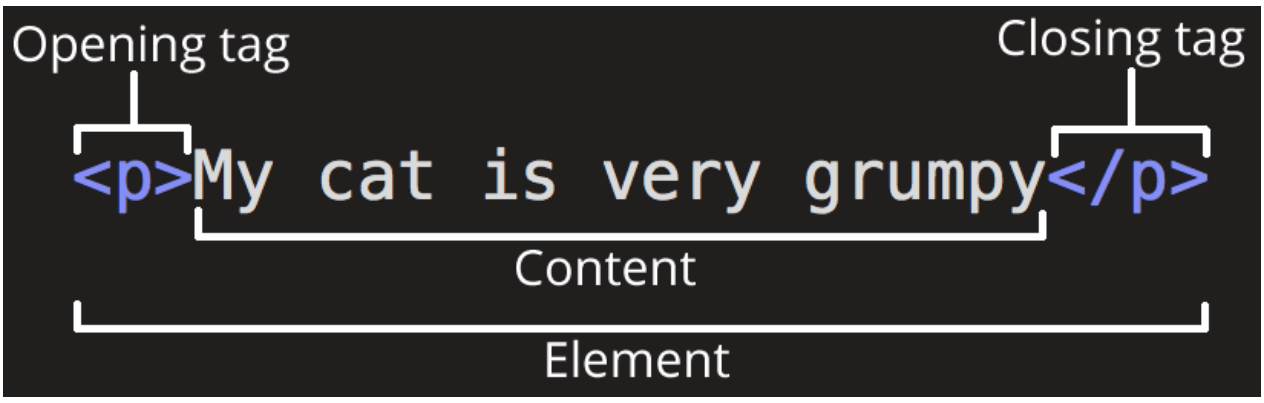


Fig. 2.1. Structure of paragraph tag

CSS stands for Cascading Style Sheets and is a set of styles that change the parameters of all components on the page. This can be anything from font size to button shadow. As a

rule, the file with styles is taken out in a separate file to structure the code in the project, and then included on the page through special commands, indicating the location of the file.

2.5. JS

Javascript is a prototype-oriented programming language. It is dynamically typed, which allows variables to get a type during variable assignment. If HTML is the basis of a web page, and CSS is its description, then JS is what makes the site "live".

JS functions:

1) Ability to change the content of the browser page;

2) Working with styles, mainly - change;

3) Cookies process;

4) Working with tags;

5) Animation.

This language is used for support by all modern browsers. He has a very low threshold of entry, which allows you to quickly master it. It is considered one of the most developed languages at the moment. There is no distinction between the types of objects, properties and methods can be added dynamically without pre-writing. The script written in this language is executed on the client side

.

A significant disadvantage is the security issue. This is explained by the fact that the code is executed on the client side and its content can be easily unloaded. For this reason, it is not advised to store sensitive information in such code. Also, for this reason, all logic, as a rule, is transferred to the backend, to the server, which basically has a lot of processing power.

On the basis of this language, countless libraries have been created for working with graphics, animation and even a backend, through Node.js.

2.6. AJAX

Stands for Asynchronous Javascript and XML. Is considered as a set of techniques for developing Javascript and XML-based web applications. In fact, this is a cooperation of the two technologies mentioned above.

It is a set of methods that allows a web application to be asynchronous, so it is possible to process requests to the server in the background. Before its introduction, applications were primarily run on the server side.

AJAX allows you to avoid re-refreshing the entire page, updating only a part of it, thus, you can significantly optimize the program's work, avoiding unnecessary load on the server and the client side.

The main advantages of using this technology:

1) Performance;

2) Low threshold of entry;

3) Ability to create a user-friendly interface;

4) Active user interaction.

There are two methods of working with AJAX: changing the page content without reloading and making a dynamic request to the server.

System usually consists of:

1) General markup of the site along with styles;

2) Document object model for displaying data;

3) Json for data exchange;

4) Javascript.

Since its inception, it has introduced a convenient mechanism for shaping the user interface. On the other hand, this made it possible to solve additional tasks that arise when creating a web application.

Due to its asynchrony, during the execution of AJAX requests, the client can continue to perform its actions without waiting for the completion of execution [26]. As a rule, in this case, the application should have some kind of indication that the process is running.

The scheme of the web application from the point of view of the client-side using AJAX and without is shown in the fig. 2.2.

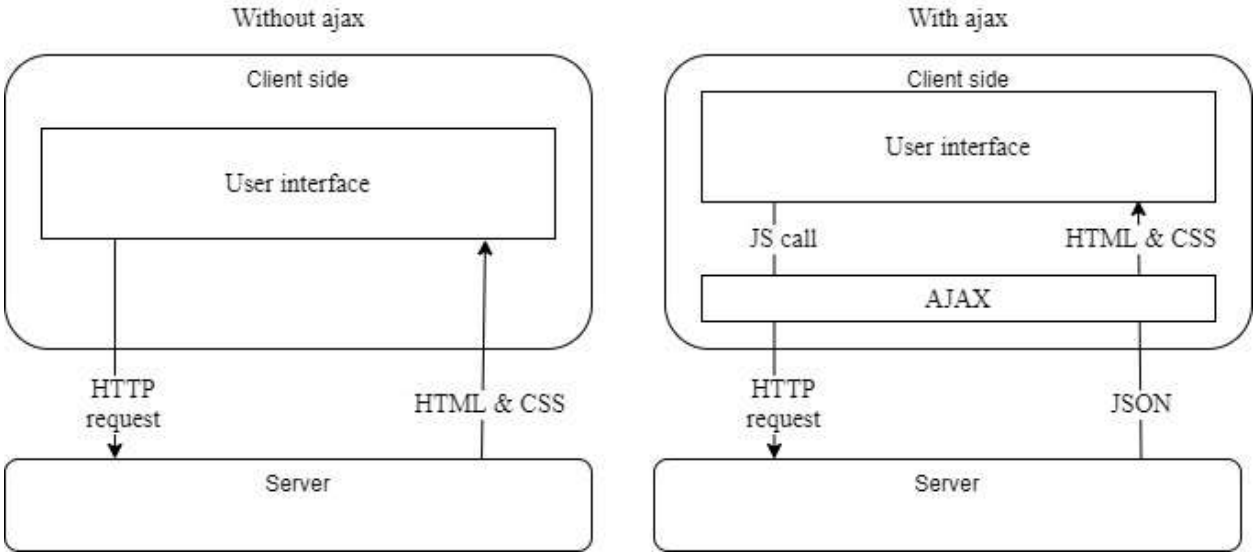


Fig. 2.2. Comparison in web application with additional layer

In the normal model, an HTTP request is sent from the browser to the server. Then the server receives variables into the controller, which are parsed, decrypted and processed. Then the necessary information is obtained from the database, after which the server sends the necessary data to the browser. After receiving the data, the browser reloads the page to draw new changes. And only after that, the user will be able to somehow interact with the application.

Agree, this approach is not always appropriate. Especially when you need, say, to draw some additional element while preserving the rest. But a request will still be sent, which will re-pull the same bunch of old values with a tiny addition of new logic, which could have been spent much less time and effort.

At the same time, using AJAX, there will be the following situation: the browser creates a JS call, which is formed into a request going to the server. It is important to note that this happens in the background and does not interfere with the client's further work in any way. After processing the request, the server returns the data back to the web browser. The browser then changes and displays the requested data without reloading.

AJAX is not always used to change the visual aspect of a web page. Sometimes there is a need to send a POST request with some information for further processing by the server

and storage in the database without any return. This situation is possible when it is necessary to send some information to the server in the background.

2.7. D3.js

D3 stands for Data-Driven Documents. It is a library of the Java script programming language, which consists of dozens of other modules created to solve different tasks: loading data, building shapes, formatting, scaling. It was created for processing and visualization, so called, “boring” data like tables, graphs [27]. The D3.js library allows you to perform group operations on elements of HTML documents, applying data from an array to them. It provides convenient mechanisms for processing data from arrays and creating DOM elements (fig. 2.3).

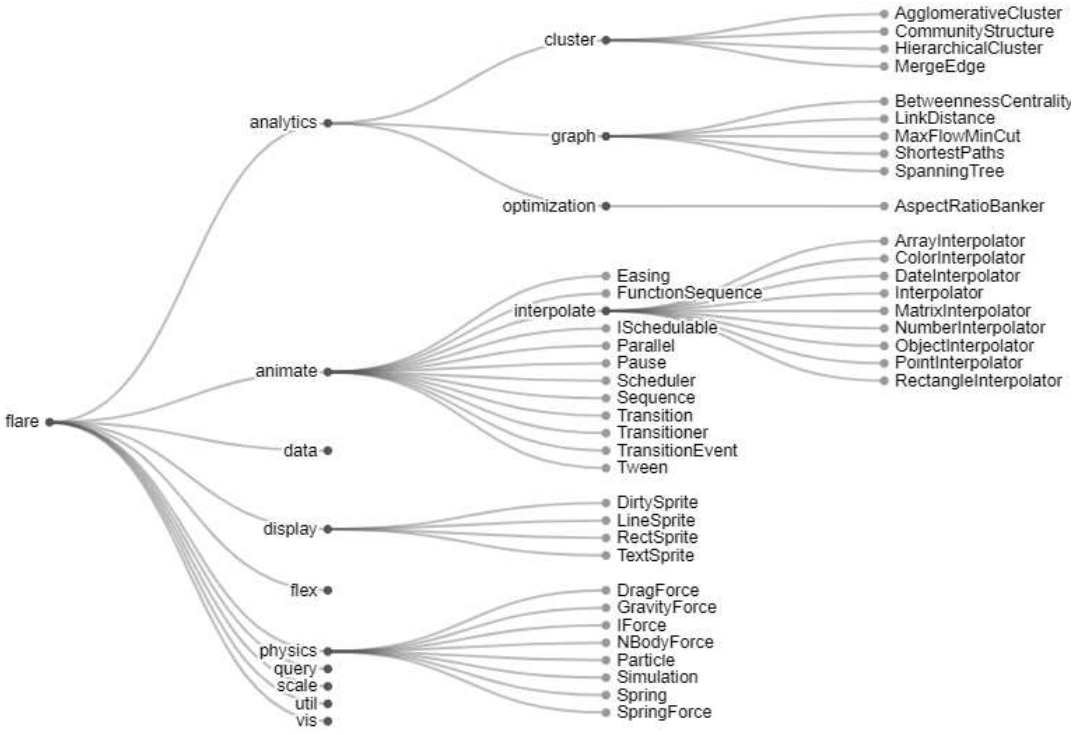


Fig. 2.3. Example of collapsible tree by means of D3.js

When writing code using this library, keep in mind that D3 implements an approach called a fluent interface. Outwardly, it looks like a chain in which each subsequent method is called on the result from the previous method.

To interact with DOM elements, a selection is first formed, on which the search for an element is called. The result is used for further work, for example, to create a subsequent selection from children. The most common mistake among developers when working with this library is an error in calling elements on a selection due to non-nesting.

As a rule, most often on the Internet, visualization is built using vector drawings in the svg format (fig. 2.4).

Fig. 2.4. Simplest vector figures

The easiest way to work with data in svg format is to transform, change position, create simple shapes. Complex shapes are built using coordinates.

The functionality of D3.js is to work with:

1) Data;

2) Scale;

3) Additional data loading;

4) Axles;

5) Events;

6) Line;

7) Other charts.

To work with DOM, D3 uses the same API for all calls.

It should also be noted that the library can animate elements and hang the animation process on some events, for example drag and drop or on pressing the mouse button, or simply when hovering over an object.

Data visualization implies greater assimilation of information and better understanding.

As a result, the implemented data visualization methods in the library turned out to be so successful that it became the basis for many other libraries for plotting.

2.8. jQuery

A JavaScript library that is designed to make it easier to work with HTML elements in the browser using more readable methods than the native DOM that JS provides.

The main advantages provided by this library are:

1) Abstraction of the DOM interface;

2) Cross-platform among browsers;

3) Fixed bugs in the browser regarding CSS and DOM.

jQuery, unlike Js, works on all versions and types of browsers, code written in it is easier to maintain and debug. It can be considered a high-level JS add-on with a low threshold of entry. Such code is more intuitive than the standard mechanism that JS provides. It is considered one of the main tools in the range of web developers and aspiring programmers.

Primary task of library is finding or creating of HTML-elements for different purposes using simple readable code. jQuery is not just simplifying interaction with native DOM but also do it with asynchronous HTTP requests of the same AJAX. But main usefulness is simplifying work with HTML.

Is is said that better to use jQuery if there is necessity to work with DOM elements instead of inventing new functionality for this, you still conclude that it has already been implemented. jQuery has been maintained and continues to be developed for over 10 years.

Without using this library, you can freely write software, it has nothing in it that is not in the same JS. The thing is, you can write with it much faster, without endless searches for attributes and methods in the DOM documentation, using intuitive methods and abstraction. It's kind of a high-level programming language compared to C or C ++. You will also have to consider the fact that without the provided library functionality, you will have to write many additional options to achieve the compatibility with different browsers that jQuery already provides.

2.9. Bootstrap 5

A client-side framework required to build websites or applications. This framework is html and css templates with a large set of ready-made components such as:

1) Elements for navigation;

2) Forms;

3) Icon sets

4) Alerts

5) Tables

6) Mesh

Grid templates should be noted separately. With their addition, the positioning of elements on the page has been greatly simplified (fig. 2.5).

Fig. 2.5. Modular grid

The container, which is taken as a basis, is conventionally divided into 12 even parts, so it is possible to indicate which components should be in which part. Parts can be combined into groups (fig. 2.6).

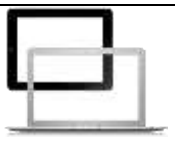
Fig. 2.6. Columns in grid

By specifying a digit in the column class, the maximum size of one is fixed, as well as the size relative to other columns. If you just use the “col” class without a number, all elements in the container with this class will become the same size, provided that the content (text for example) allows.

Another great feature of Bootstrap is its grid options. With their help, you can use different settings for devices of different extensions. A comparative table with the indicated dimensions of the visibility zones of the devices are shown in the table 2.1.

Table 2.1

Parameters of Grids

					
Name	Extra small <576px	Small ≥576px	Medium ≥768px	Large ≥992px	Extra large ≥1200px
Max width	None (auto)	540px	720px	960px	1140px
Prefix	.col	.col-sm	.col-md	.col-lg	.col-xl
Numbers of columns	12				

This pattern allows you to greatly simplify mobile development for web applications without complicating the application architecture with unnecessary files where you would have to save style files.

Recent versions began to support the flexbox template, which itself made dynamic layout much easier. With its help, it is possible to dynamically position elements in any part of the screen, in groups, one by one, in a certain order, to narrow and stretch the elements.

Conclusions of the second part

In the second part, two main components of any web application were considered - the backend and the frontend. The frontend is the entire visual component of any web product. HTML acts as a "skeleton" of the page, marking up the main markup of the page. CSS takes responsibility for styling HTML components. With it, you can change shapes, indents, colors. From banner size to font tilt. It is also possible to create animations. With Bootstrap's presets, you can conveniently arrange page elements using a grid, as well as dynamically change components and their content depending on the screen size. Js is a prototype-based programming language that controls the behavior of components on a page. It is fast and easy to learn. AJAX has been used to dynamically load information in the background without reloading the page.

The backend is a more complex system that is completely responsible for the logic of the web application, as well as the formation of interfaces through which the user will interact with the application. Also, the backend includes the database and work with it, such as: creating, reading, updating, deleting records. To communicate with the database, EF was used. The web application backend of this thesis is written in C # using ASP.NET technology.

PART 3
APPLICATION DESIGN

In this part, based on already researching information about methodologies for planning business resources, as well as studying individual modules, the development of a web application by means of ASP.NET technology and others will be considered.

3.1. Architecture of the program

When creating your web application, you need to take responsibility for its architecture. This is the foundation of any application on the quality of which all further development depends. Whether the application is easy to maintain and expand depends primarily on the architecture. In a well-designed application, all modules work like gears in a large machine. And in case of failure, it should be immediately clear where the reason is, in order to understand what the reason is without going through all the functionality of this mechanism. Now there are a lot of new technologies that can completely replace the existing ones and the application should be built in such a way as not to be tied to a specific framework. This and other principles have been detailed in Robert C. Martin's book “Clean Architecture” [28]. The principles of clean architecture are as follows:

1) Business logic should not depend on the database;

2) The user interface should change without the need to make changes to the business logic;

3) Testing should be able to be performed without a database and user interface;

4) The architecture of the application should not adapt to the framework, but vice versa.

As a basis, the architectural template MVC which stands for Model-View-Controller [29] was chosen. An exaggerated image that gives a general idea of what each part of MVC is responsible for is shown in fig. 3.1.

Fig. 3.1. Abstract representation of MVC

Functions of controller:

1) Processing incoming variables;

2) Formation of requests for sending and receiving information;

3) Handling of exceptions and errors;

4) Logging.

Functions of model:

1) Checking incoming parameters;

2) Working with DBMS;

3) Data processing for visualization;

4) Program logic processing.

Functions of View is only visualization of program results.

3.1.1. Advantages and disadvantages of MVC

MVC, like any other architecture pattern, as well as everything that a person creates, has both advantages and disadvantages.

MVC advantages:

1) Concept;

2) Easiness of debugging.

Like any other template, MVC was originally conceived as a unification of some specific rules for organizing code sections that make up a project. This is undoubtedly a key

factor that affects the speed of interaction between developers. This also applies to new developers, they may not know the features of the project, but at the same time be familiar with this template, which is why they can quickly grasp the details and get to work.

It is easy to debug still due to the structuring of the project as a whole. If, for example, an error occurs in the logic of the project, then the problem should accordingly be looked for in the code that is responsible for the business logic. This approach speeds up not only writing code and cooperation with other developers in the project, but also fixing errors in existing code.

However, MVC has its drawbacks:

1) Heavy load on servers;

2) Complexity of division into modules;

3) Difficult expansion of a program.

While the functional parts are independent and interact with each other only by sending data, this requires significant computing resources from the servers.

Clarity in dividing the program into modules gives clarity, but its design and writing of functionality in all three parts is quite time consuming.

All functionality should be divided in three functional layers (fig. 3.2)

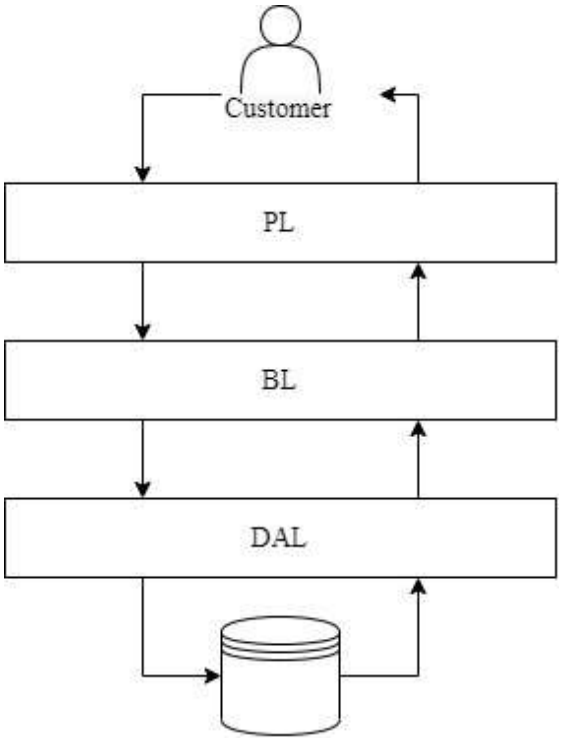


Fig. 3.2. Functional layers

3.2. Database structure

Script for database creation is shown in Appendix A.

Diagram of database is shown in Appendix B.

The database is represented as a set of tables, using different types of connection (One-to-One (Chain and Item tables), One-to-Many and Many-to-Many). All in all, there are 18 tables implemented in the database.

1) md.BOM – the table, which represents the Bill of Material, which contains Bill of Materials, needed for creating a specific item.

Table 3.1

md.BOM

Column name	Data type	Length	Purpose	Integrity constraint
1	2	3	4	5
BOMId	integer		Unique ID.	PRIMARY KEY UNIQUE
ItemsJson	nvarchar	max	Contains bill of materials, needed for creating a specific item.	

2) md.Chain – the table, which represents the chain of operations, which are used for creating the specific item. Every chain is linked to the specific item, because different items can have different sequence of operations to be created.

Table 3.2

md.Chain

Column name	Data type	Length	Purpose	Integrity constraint
1	2	3	4	5
ChainId	integer		Unique ID.	PRIMARY KEY UNIQUE
ItemId	integer		Unique id field, needed for connection with md.Item table.	Cannot be NULL, FOREIGN KEY REFERENCES md.Item (ItemId)

3) md.ChainNode – the table, which represents the chain node of the operations chain, which are used for creating the specific item. Every chain node is linked to the specific chain.

Table 3.3

md.ChainNode

Column name	Data type	Length	Purpose	Integrity constraint
1	2	3	4	5
ChainNodeId	integer		Unique ID. with md.Task table.	PRIMARY KEY UNIQUE REFERENCES md.Task (TaskId

Continuation of the Table 3.3

1	2	3	4	5
ParentTaskId	integer		Unique id field, needed for connection with md.Task table. User for creating a linked list as a chain of nodes.	Cannot be NULL, FOREIGN KEY REFERENCES md.Task (TaskId)
ChainId	integer		Unique id field, needed for connection with md.Chain table.	Cannot be NULL, FOREIGN KEY REFERENCES md.Chain (ChainId)

4) md.Employee – the table, which represents the Employee entity. Employee can have different roles and represents the real worker in the system. Employees will produce requests on some warehouse operations, like receiving, shipment, etc.

Table 3.4

md.ChainNode

Column name	**Data type**	**Length**	**Purpose**	**Integrity constraint**
1	2	3	4	5
EmployeeId	integer		Unique ID.	PRIMARY KEY UNIQUE
EmployeeName	nvarchar	50	Defines an employee`s name.	Cannot be NULL

Continuation of the Table 3.4

1	2	3	4	5
EmployeeSurname	nvarchar	50	Defines an employee`s surname.	Cannot be NULL
EmployeeMail	nvarchar	50	Defines an employee`s mail.	Cannot be NULL
EmployeePassword	nvarchar	50	Defines an employee`s password.	Cannot be NULL
EmployeeRoleId	integer		Unique id field, needed for connection with md.Role table.	Cannot be NULL, FOREIGN KEY REFERENCES md.Role (RoleId)
EmployeeLogin	nvarchar	50	Defines an employee`s login.	Cannot be NULL

5) md.Item – the table, which represents the Item entity. Item – is the essential one of the almost every action in the system. It can be either a part of some good or a finished good as well.

Table 3.5

md.Item

Column name	**Data type**	**Length**	**Purpose**	**Integrity constraint**
1	2	3	4	5
ItemId	integer		Unique ID.	PRIMARY KEY UNIQUE

Continuation of the Table 3.5

1	2	3	4	5
ItemDescription	nvarchar	50	Represents the description of an item	Cannot be NULL
MakeBuy	nvarchar	4	Defines whether an item is made or bought	Cannot be NULL
isFinal	bit		Defines if the item is final or not	Cannot be NULL
BomId	integer		Unique id field, needed for connection with md.BOM table.	Cannot be NULL, FOREIGN KEY REFERENCES md.BOM (BomId)
UomId	integer		Unique id field, needed for connection with md.UOM table.	Cannot be NULL, FOREIGN KEY REFERENCES md.UOM (UomId)

6) md.ItemLocation – the table, that represents a place, in which Items are served and stored. Can connect the only one item per one location.

Table 3.6

md.ItemLocation

Column name	Data type	Length	Purpose	Integrity constraint
ItemLocationId	integer		Unique ID.	PRIMARY KEY UNIQUE
ItemId	integer		Unique id field, needed for connection with md.Item table.	Cannot be NULL, FOREIGN KEY REFERENCES md.Item (ItemId)
LocationId	integer		Unique id field, needed for connection with md.Location table.	Cannot be NULL, FOREIGN KEY REFERENCES md.Location (LocationId)
InventoryOnHand	decimal	(18, 0)	Defines inventory quantity in a place	Cannot be NULL
InventoryAvailable	decimal	(18, 0)	Defines inventory quantity in a place	Cannot be NULL

7) md.Location – the table, which represents the location of the warehouse. Location has a location code, associated with some real location in the world.

Table 3.7

md.Location

Column name	Data type	Length	Purpose	Integrity constraint
LocationId	integer		Unique ID.	PRIMARY KEY UNIQUE
LocationName	nvarchar	50	Defines a name of location	Cannot be NULL
LocationCode	nvarchar	50	Defines a code of location	Cannot be NULL

8) md.ReceivingHistory – the table, which defines the history of the receiving operation. The history is stored in the ModifiedData field in the JSON format.

Table 3.8

md.ReceivingHistory

Column name	Data type	Length	Purpose	Integrity constraint
ReceivingHistoryId	integer		Unique ID.	PRIMARY KEY UNIQUE
ModifiedData	nvarchar	MAX	Defines a name of location	Cannot be NULL
ItemLocationId	integer		Unique id field, needed for connection with md.ItemLocation table.	Cannot be NULL, FOREIGN KEY REFERENCES md.ItemLocation (ItemLocationId)

9) md.Request – the table, which defines the request on the operation, provided by an employee.

Table 3.9

md.Request

Column name	Data type	Length	Purpose	Integrity constraint
1	2	3	4	5
RequestId	integer		Unique ID.	PRIMARY KEY UNIQUE
RequestTypeId	integer		Unique id field, needed for connection with md.RequestType table.	Cannot be NULL, FOREIGN KEY REFERENCES md.RequestType (RequestTypeId)
RequestBody	nvarchar	MAX	Defines the request`s data	PRIMARY KEY UNIQUE
ItemLocationId	integer		Unique id field, needed for connection with md.ItemLocation table.	Cannot be NULL, FOREIGN KEY REFERENCES md.ItemLocation (ItemLocationId)
EmployeeId	integer		Unique id field, needed for connection with md.Employee table.	Cannot be NULL, FOREIGN KEY REFERENCES md.Employee (EmployeeId)

10) md.RequestType – the table, which describes the types of requests.

Table 3.10

md.RequestType

Column name	Data type	Length	Purpose	Integrity constraint
RequestTypeId	integer		Unique ID.	PRIMARY KEY UNIQUE
RequestType	nvarchar	40	Defines the request`s type	Cannot be NULL

11) md.Lot – the table, which defines the lot entity. Lot is used for storing items themselves. Lot is located on some location. It is the main entity for employee`s operations.

Table 3.11

md.Lot

Column name	Data type	Length	Purpose	Integrity constraint
LotId	integer		Unique ID.	PRIMARY KEY UNIQUE
LotNumber	nvarchar	40	Defines the lot number	Cannot be NULL
ItemLocationId	integer		Unique id field, needed for connection with md.ItemLocation table.	Cannot be NULL, FOREIGN KEY REFERENCES md.ItemLocation (ItemLocationId)
InventoryQty	decimal	(18, 0)	Defines the inventory quantity in the lot	Cannot be NULL

12) md.Role – the table, which defines the employee roles. Role defines the set of features (buttons), which are opened for the employee`s usage. Some features are meant to be used by the very limited roles.

Table 3.12

md.Role

Column name	Data type	Length	Purpose	Integrity constraint
RoleId	integer		Unique ID.	PRIMARY KEY UNIQUE
Role	nvarchar	40	Defines the role	Cannot be NULL

13) md.ShipmentHistory – the table, which defines the history of the shipment operation. The history is stored in the ModifiedData field in the JSON format.

Table 3.13

md.ShipmentHistory

Column name	Data type	Length	Purpose	Integrity constraint
ShipmentHistoryId	integer		Unique ID.	PRIMARY KEY UNIQUE
ModifiedData	nvarchar	MAX	Defines a name of location	Cannot be NULL
ItemLocationId	integer		Unique id field, needed for connection with md.ItemLocation table.	Cannot be NULL, FOREIGN KEY REFERENCES md.ItemLocation (ItemLocationId)

14) md.Task – the table, which defines the specific task, provided by the manufacture. It can be grinding, electroerosion, waterjet cutting, sandblasting, etc.

Table 3.14

md. Task

Column name	Data type	Length	Purpose	Integrity constraint
TaskId	integer		Unique ID.	PRIMARY KEY UNIQUE
TaskName	nvarchar	70	Defines the name of the task	Cannot be NULL

15) md.TaskInProgress – the table, which defines the task which is in progress at the current moment.

Table 3.15

md.TaskInProgress

Column name	Data type	Length	Purpose	Integrity constraint
1	2	3	4	5
TaskInProgressId	integer		Unique ID.	PRIMARY KEY UNIQUE
TaskId	integer		Unique id field, needed for connection with md.Task table.	Cannot be NULL, FOREIGN KEY REFERENCES md.Task (TaskId)

Continuation of the Table 3.15

1	2	3	4	5
ItemInputId	integer		Unique id field, needed for connection with md.Item table.	Cannot be NULL, FOREIGN KEY REFERENCES md.Item (ItemId)
ItemInputId	integer		Unique id field, needed for connection with md.Item table.	Cannot be NULL, FOREIGN KEY REFERENCES md.Item (ItemId)
ItemInputQty	decimal	(18, 0)	Defines the item quantity on the output.	Cannot be NULL
ItemOutputQty	decimal	(18, 0)	Defines the item quantity on the input.	Cannot be NULL
ItemLocationId	integer		Unique id field, needed for connection with md.ItemLocation table.	Cannot be NULL, FOREIGN KEY REFERENCES md.ItemLocation (ItemLocationId)

16) md.TransferringHistory – the table, which defines the history of the shipment operation. The history is stored in the ModifiedData field in the JSON format.

Table 3.16

md.TransferringHistory

Column name	Data type	Length	Purpose	Integrity constraint
TransferringHistoryId	integer		Unique ID.	PRIMARY KEY UNIQUE
ModifiedData	nvarchar	MAX	Defines a name of location	Cannot be NULL
ItemLocationId	integer		Unique id field, needed for connection with md.ItemLocation table.	Cannot be NULL, FOREIGN KEY REFERENCES md.ItemLocation (ItemLocationId)

17) md.UOM – the table, which defines unit of measure of item. It depends on the item description. If the material can be considered as a part of some other items – the UOM can be represented as powder, pieces, etc.

Table 3.17

md.UOM

Column name	Data type	Length	Purpose	Integrity constraint
UOMId	integer		Unique ID.	PRIMARY KEY UNIQUE
UomName	nvarchar	20	Defines the name of the unit of measure	Cannot be NULL

18) md.Vendor – the table, which defines the vendor entity. Vendor – is a subject, that delivers some items.

Table 3.18.

md.Vendor

Column name	**Data type**	**Length**	**Purpose**	**Integrity constraint**
VendorId	integer		Unique ID.	PRIMARY KEY UNIQUE
VendorName	nvarchar	50	Defines the name of the vendor	Cannot be NULL
VendorMail	nvarchar	50	Defines the mail of the vendor	Cannot be NULL
VendorAddress	nvarchar	150	Defines the address of the vendor	Cannot be NULL

Among the lots of entities in the database the most important of them can be defined. These entities are used mostly in all the features in the software product, so that's why they can be called as especially important for us. These entities are the following ones:

1) Item;

2) ItemLocation;

3) Vendor;

4) Task.

Item – is the main one, talking about the processes, which are shown in the current modules of the MRP system. It is used in all possible transactions between lots or warehouses (which are represented as ItemLocation entity in the database) and it is the main

one for the production set of features, represented by Task tables. Item can be as finished product (the isFinished flag shows us whether the item is finished or not) or can still be used in the creating other items in the Task processes.

ItemLocation – is a table, that shows us all warehouses and processes, which can be provided on the inventory, located in the warehouses (especially in lots, which are in turn located in the warehouse, means in the Item-Locations). By ending all tasks update the InventoryOnHand and InventoryAvailable fields values. These fields show us how much items we have on the certain location with one item type (described in the ItemDescription field).

Task – is a table, that defines tasks, which can be performed on the items during their creation or creation of other items by using the current ones as ingredients for new ones. Tasks are widely used in different places in the production set of features in the Production Module of the MRP system itself.

Vendor – a subject (person or another company), which supplies the current manufacture with certain item or items using a Receiving feature in the module of Warehouse Management. It updates InventoryOnHand field value when the operation is totally completed. Vendor table is not connected to other tables with some connection types, so then in the software product it is used as a drop-down list in some different forms or modal windows.

3.3. Design patterns

Patterns, unlike an algorithm, are not a clear list of instructions to be executed. It is rather a general description of a solution to a specific problem [30].

3.3.1. Singleton

Singleton is a generating design pattern that ensures that a class has only one instance and provides a global access point to it... This pattern is necessary when we have one shared resource that needs to be limited to concurrent access. In the web application that is

developed in this thesis, such a resource is an instance of the database context class. The program is written in such a way that only one context can be created at a time. This is necessary in order to exclude a number of errors that arise when the rules for using shared resources are violated, for example, a parallel record in which one user will have outdated data, since he unloaded them at the time of updating by another user [31].

3.3.2. UnitOfWork

In order to avoid the formation of many small queries to the database, which will slow down the work, the Unit of Work pattern is used. This entire batch of requests is recorded within the execution of one business process. Also, this pattern makes it easier to work with different repositories and guarantees the use of the same data context [32].

3.3.3. Repository

This pattern provides abstraction of connecting to any data sources (fig. 3.3).

That is, using this pattern can greatly help in the case of a transition from SQL to Firebird, for example. It is also used to describe a set of queries to a database [33].

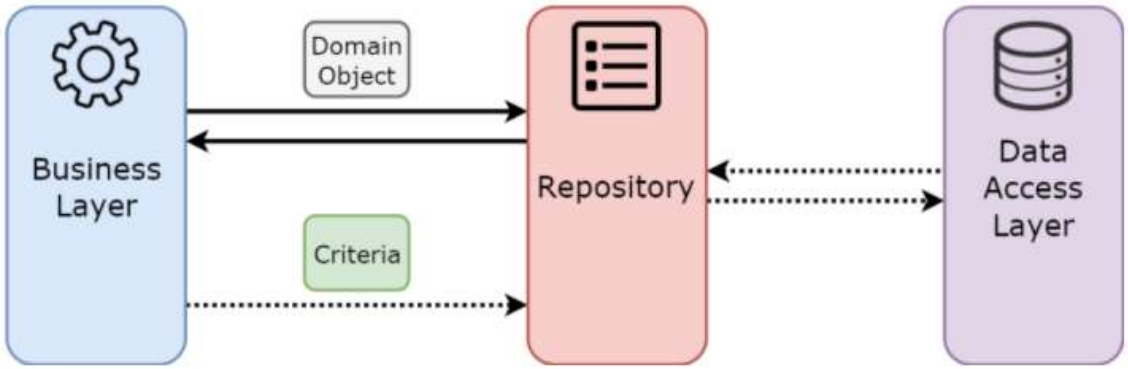


Fig. 3.3. Pattern Repository scheme

3.4. System modules

The entire web application can be conditionally divided into two components in terms of functionality: the first part is responsible for the operation of the warehouse, and second is module concerned manufacturing processes.

Both modules have common database which is fundamental of every ERP-type system. Modules have some common tables in use which are: md.Employee, md.ItemLocation and md.Lot

3.4.1. WMS module

Subsystem, which solves a number of issues related to warehouse issues of the enterprise, such as: shipping-loading of goods, storage. It optimizes the processes associated with the work of the warehouse. The primary task of the warehouse management system is to monitor the current state of resources in the warehouse, that is, balances with an exact indication of the storage location for operational access by personnel.

Module has following screens:

1) Receiving;
2) Transferring;
3) Shipment;
4) Product information;
5) Inventory;
6) Tasks.

It is important to note that the WMS module was originally planned for use from mobile devices. Therefore, for all the screenshots of this module, an adaptive layout was made for different mobile applications using Bootstrap.

Receiving is a screen designed for displaying information about items which are coming (screenshot 3.1).

Screenshot. 3.1. Receiving screen

The screen works as follows:

1) The operator generates a new order to receive;

2) The corresponding record appears in the md.Request table, as well as the Tasks display;

3) The employee takes on the task. Now he has this task displayed on the Receiving screen;

4) After that, the user unloads the goods from a certain line, then clicks on it, it becomes dark orange, and on the approve button;

5) The completed order is sent to the md.Lot table for the lot with id = 0; This is an indexer that the goods have been unloaded and are in the further distribution area. In md.ItemLocation fields InventoryOnHand and InnventoryAvaliable are updating.

The next step in working with the received product is working with the Transferring screen (screenshot 3.2).

Screenshot 3.2. Transferring screen

Transferring screen works as follows:

1) The operator generates a new order to transfer;

2) The corresponding record appears in the md.Request table, as well as the Tasks display;

3) The employee takes on the task. Now he has this task displayed on the Transferring screen;

4) On screen worker already gets all information like itemkey, which is already sticked on pallet or boxes during previous stage, quantity and location where he should transfer it.

5) After transferring in user press approve button and then md.Lot correspond fields are changing.

It is necessary to notify that after inputting item key and pressing enter AJAX request appears which then get information from backend where exactly is this item, in which lots.

Next screen which will be observed is Shipment screen (screenshot 3.3).

Screenshot 3.3. Shipment screen

The screen works as follows:

1) The operator generates a new order to shipment;

2) The corresponding record appears in the md.Request table, as well as the Tasks display;

3) The employee takes the task. Now he has this task displayed on the Shipment screen;

4) After that, the user package the goods from a certain line, then clicks on it, it becomes dark orange, and on the approve button;

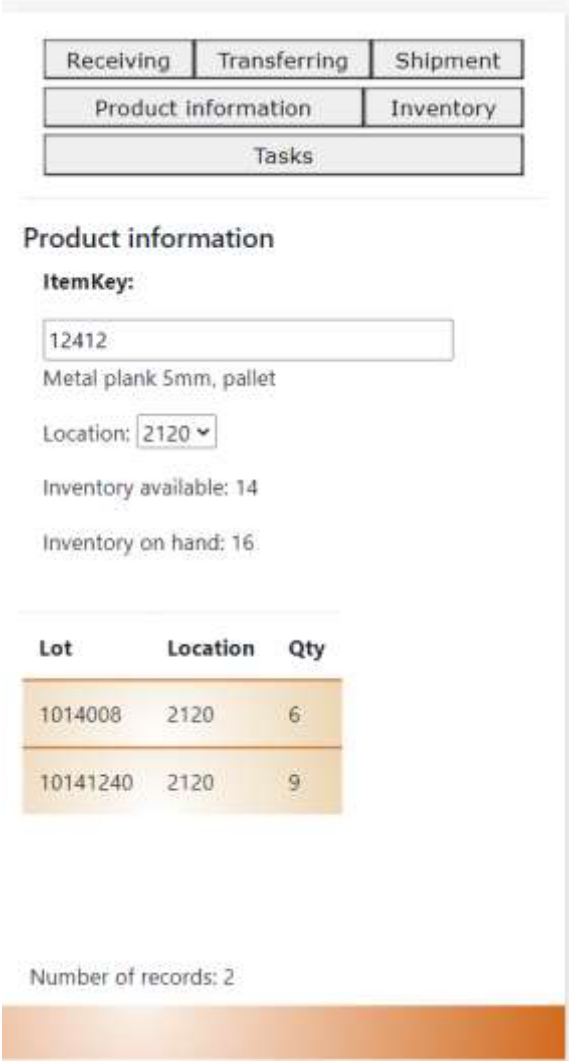
5) In md.ItemLocation fields InventoryOnHand and InventoryAvaliable are updating.

Main purpose of product information screen is showing information about product as well as lots where it located (screenshot 3.4).

Transferring screen works as follows:

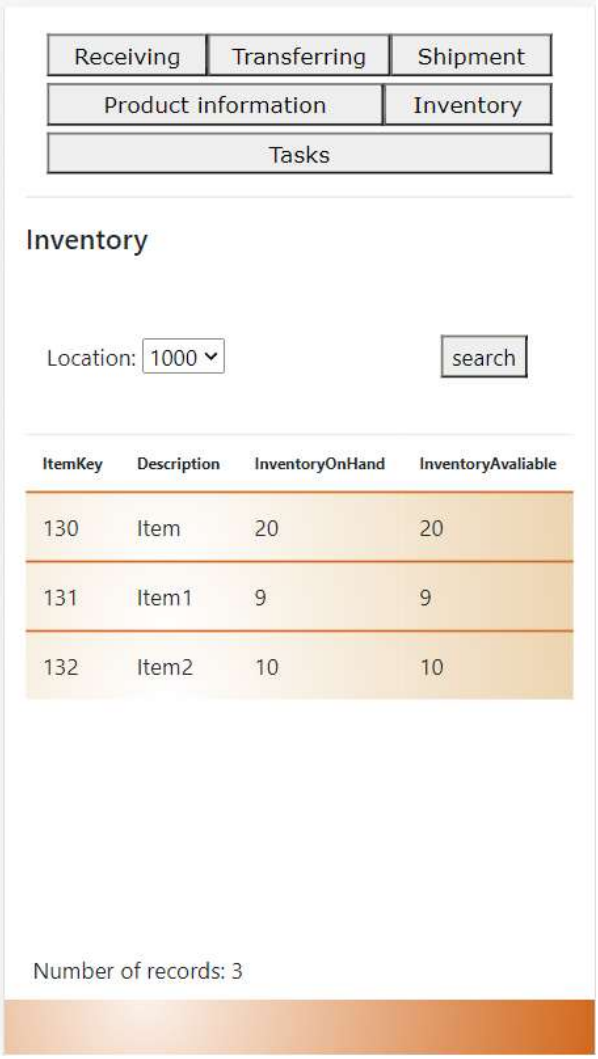
1) User input desired item key in choose location then press approve.

2) User gets general information about item as well as quantity of item which is available and on hand. Also, user gets information about all lots where item key is located with quantity.



Screenshot 3.4. Product Information screen

Inventory screen shows all items which are in the warehouse (screenshot 3.5). To work with it, user should choose location and then press search button.



Screenshot 3.4. Inventory screen

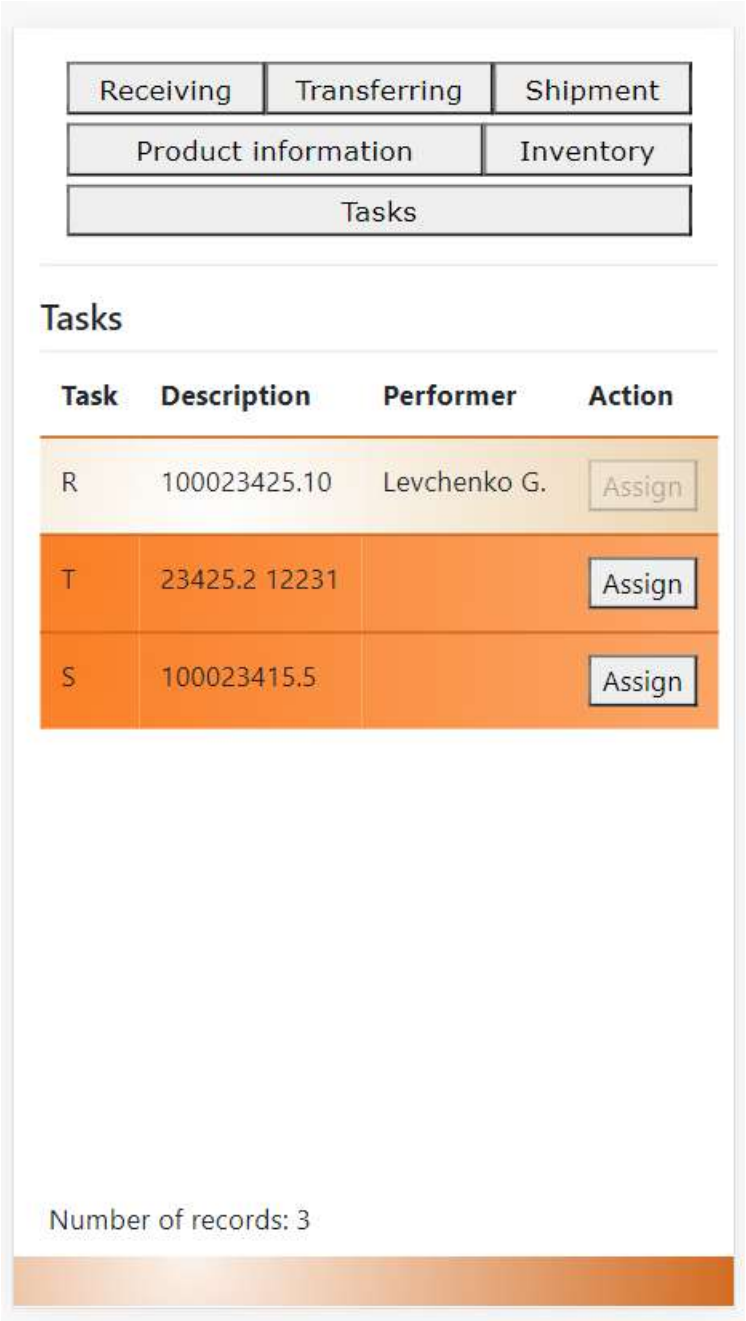
Last screen of WMS module is Tasks screen (screenshot 3.5). All tasks which operator or chief create are being added to this screen.

The screen works as follows:

1) Creation of tasks by operator;

2) Self assigning of task by worker;

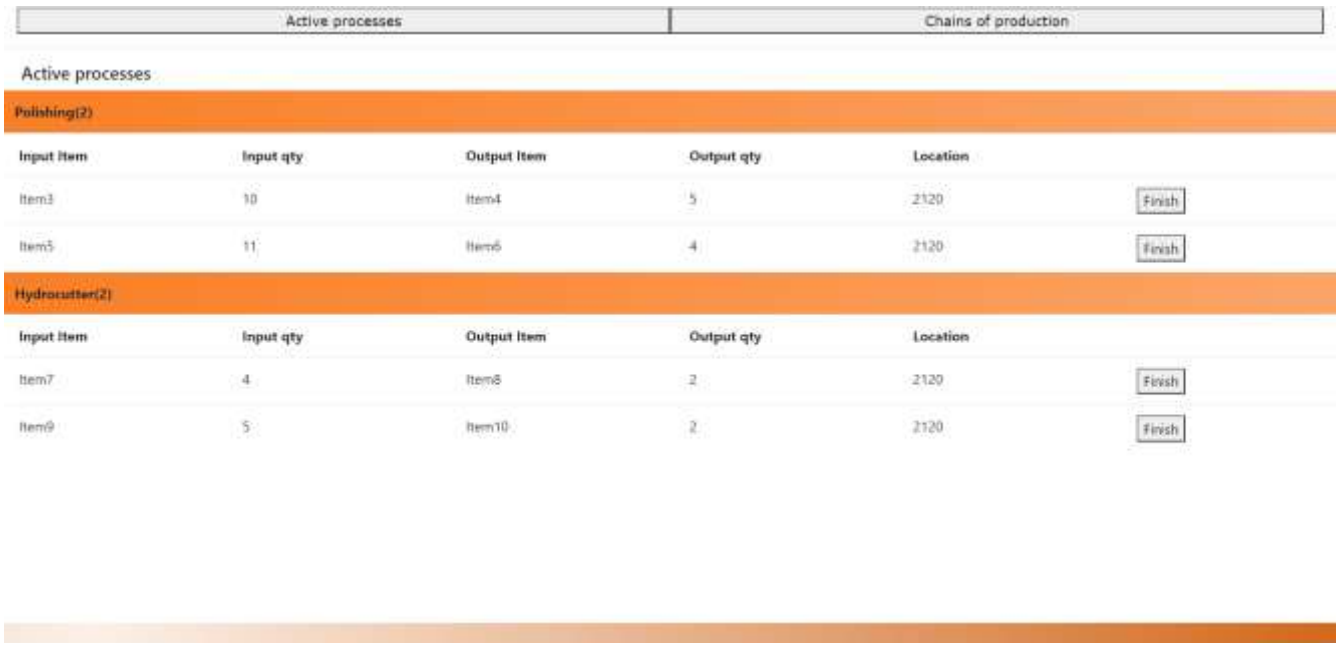
3) Task is assigned on worker and become disabled for all other workers. But chief sees current execution of the task. This is gets by using field EmployeeId which is null from the start. And when is assigned – EmployeeId is written and button assign becomes inactive. Note 100023425.10 means that it is item key 100023425 and quantity equals 10. What should be done with this item is written in field task where r – receiving, t – transferring and s – shipment.



Screenshot 3.5. Tasks screen

3.4.2. Manufacturing Module

The second module that is implemented in this web application is a module for tracking resources that are in certain stages of production. There is already a lot of information on the screenshots of this module, so it was decided to make the screen size the size of a laptop / computer monitor (screenshot 3.6).



Screenshot 3.6. Active processes screen

In this screenshot, users can see which processes are currently active, which resources are involved and what will be the output. It is also possible to end the current process and proceed to the next one in the chain, if this is not the last stage of production.

Conclusions of the third part

In this part, we examined the MVC architecture of the application, its pros and cons. Also, the design patterns that were used during the development of the web application were considered. As a result of the work, a web application was created consisting of two modules - WMS and a module for monitoring material resources in production. The modules are interconnected by a common base.

CONCLUSIONS

During the course of the thesis, main methodologies of resource planning were observed. The step-by-step development of MRP-type systems, as well as individual modules and their interaction with each other, such as WMS - for inventory, tracking the movement of goods in the warehouse, shipment and loading of goods, to obtain general information about the goods in the warehouse, or MPS, were considered. which gives the information needed to plan and control the manufacturing operation.MRP 2 became the founder of the principles of detailed enterprise resource planning, which includes capacity utilization planning, production planning, supply and sales planning, production modeling, batch planning, construction and adjustment of the operational plan and tasks. Also, all the modules that make up MRP 2 and ready-made ERP solutions from other companies were considered in detail.

In order to develop a web application, related technologies were studied to achieve the result. Rendering the page - with HTML, CSS and Bootstrap. Convenient access to page DOM elements using JS and jQuery. With the help of AJAX, good productivity of the application was achieved due to the absence of page reloading to display additional information.

After studying the theoretical information, a web application was created, consisting of two modules, which will allow small businesses to get a good growth in development thanks to the constant monitoring of resources, as well as relevant information that will now be provided by this system. Since only the most basic features of MRP have been taken, such a program will be affordable and will have a good ratio: price-potential of the company's development.

REFERENCE LIST

1) Kovalev I.G. Economy and modern state of Great Britain political structure / I.G. Kovalev. — M.: Pero, 2011. — 340 p.

2) Taylor F. W. The Principles of Scientific Management / F. W. Taylor, 1911. — 144 p.

3) Emerson H. The twelve principles of efficiency / H. Emerson. — N.Y.: The Engineering Magazine Co, 1912. — 423 p.

4) Why is MRP important, 2020. [Electronic resource] – Access mode: https://searcherp.techtarget.com/definition/material-requirements-planning-MRP

5) What Is Material Requirements Planning, Yury Rachitsky, 2020. [Electronic resource] – Access mode: https://www.smartsheet.com/guide-to-material-requirements-planning

6) Landvater Darryl V. MRP II Standard System. A handbook for Manufacturing Software Survival / Darryl V. Landvater, and Christopher D. Gray. — N.J.: John Wiley & Sons, Inc., 1989. — 352 p.

7) CRP (Continuous Replenishment Program), Asprova Corporation, 2008. [Electronic resource] – Access mode: http://www.lean-manufacturing-japan.com/scm-terminology/crp-continuous-replenishment-program.html

8) Powell Niland Production Planning, Scheduling, and Inventory Control: A Text and Cases / Niland Powell. – N.: Macmillan, 1970. – 553 p.

9) WMS - система управления складом, 2018. [Electronic resource] – Access mode:https://www.it.ua/ru/knowledge-base/technology-innovation/warehouse management-system-wms

10) What is demand management? [Electronic resource] – Access mode: https://www.cips.org/knowledge/procurement-topics-and-skills/operations-management/demand-management/

11) Sales Management Definition, Process, Strategies and Resources, 2020. [Electronic resource] – Access mode: https://www.pipedrive.com/en/blog/sales-management

12) Order Management subsystem, 2020. [Electronic resource] – Access mode: https://help.hcltechsw.com/commerce/9.1.0/developer/concepts/cosordsu.html

13) Manufacturing Resource Planning Definition, Adam Hayes, 2020. [Electronic resource] – Access mode: https://www.investopedia.com/terms/m/manufacturing-resource-planning.asp

14) Выполнение полного планирования, MPS или MRP, Soren Groes Peterson, 2020. [Electronic resource] – Access mode: https://docs.microsoft.com/ru-ru/dynamics365/business-central/production-how-to-run-mps-and-mrp

15) DRP, 2020. [Electronic resource] – Access mode: https://uk.wikipedia.org/wiki/DRP

16) ERP - планирование ресурсов предприятия, 2020. [Electronic resource] – Access mode: https://www.it.ua/ru/knowledge-base/technology-innovation/enterprise-resource-planning-erp

17) Zeng Y. Risk Management For Enterprise Resource Planning System Implementations in Project-Based Firms : dis. for the degree of PHD / Zeng Yajun, Maryland, 2010. — 210 p.

18) OptiProERP, 2020. [Electronic resource] – Access mode: https://www.optiproerp.com/

19) БУХта, 2020. [Electronic resource] – Access mode: http://www.erp-online.ru/software/buhta/

20) Work the way that works for you, 2020, Monday. [Electronic resource] – Access mode: https://monday.com/

21) CLOBBI, 2020. [Electronic resource] – Access mode: https://clobbi.com/ru/operativnyy-uchet-i-kontrol-proizvodstva-produktsii/

22) Intelligent ERP, CRM Software & Remote Workforce Management, 2020. [Electronic resource] – Access mode: https://www.workwisellc.com/

23) .NET Framework, Microsoft, 2020. [Electronic resource] – Access mode: https://ru.wikipedia.org/wiki/.NET_Framework

24) SQL, Raymond Boys, 2020. [Electronic resource] – Access mode: https://ru.wikipedia.org/wiki/SQL

25) Entity Framework 6, Arthur Vickers, 2020. [Electronic resource] – Access mode: https://docs.microsoft.com/en-us/ef/ef6/

26) AJAX, Mozilla and individual contributors, 2005-2020. [Electronic resource] – Access mode: https://developer.mozilla.org/ru/docs/Web/Guide/AJAX

27) Просто о D3.js, Anton Gcor, 2017. [Electronic resource] – Access mode: https://habr.com/ru/post/342106/

28) Martin Robert Clean Architecture: A Craftsman's Guide to Software Structure and Design / Robert Martin. – N.J.: Prentice Hall, 2018. – 404 p.

29) Model View Controller (MVC) опыт использования, выводы [Internet Resources] / Web- site: habr; Access mode: https:// https://habr.com/ru/post/249263/, free.

30) Каталог патернів проектування [Internet Resources] / Web-site: refactoring.guru; Access mode: https://refactoring.guru/uk/design-patterns/catalog, free

31) Implementing the Singleton Pattern in C#. [Electronic resources] – Access mode: https://csharpindepth.com/articles/singleton

32) Unit of Work Design Pattern, Shivprasad Koirala, 2013. [Electronic resource] – Access mode: https://www.codeproject.com/Articles/581487/Unit-of-Work-Design-Pattern

33) Repository and Unit of Work Pattern, Wolfgang Ofner, 2018. [Electronic resource] – Access mode: https://www.programmingwithwolfgang.com/repository-and-unit-of-work-pattern/

APPENDIX A

Sql script for db creation

```
/*********************************************************************/
/*_____________________________CREATING DATABASE_____________________________*/
/*********************************************************************/

CREATE DATABASE MRPDB
FO

USE MRPDB

CREATE SCHEMA md
GO

/*********************************************************************/
/*_____________________________CREATING TABLES_____________________________*/
/*********************************************************************/

CREATE TABLE md.Item (
       ItemId INT PRIMARY KEY,
       ItemDescription NVARCHAR(50) NOT NULL,
       isFinal BIT NOT NULL,
       MakeBuy NVARCHAR(4) NOT NULL,
       BomId INT NULL,
       UomId INT NOT NULL
);

CREATE TABLE md.UOM (
       UOMId INT PRIMARY KEY,
       UomName NVARCHAR(20) NOT NULL
);

CREATE TABLE md.BOM (
       BOMId INT PRIMARY KEY,
       ItemsJson NVARCHAR(MAX) NOT NULL
);

CREATE TABLE md.ItemLocation (
       ItemLocationId INT PRIMARY KEY,
       ItemId INT NOT NULL,
       LocationId INT NOT NULL,
       InventoryOnHand DECIMAL NOT NULL,
       InventoryAvailable DECIMAL NOT NULL
);

CREATE TABLE md.[Location] (
       LocationId INT PRIMARY KEY,
       LocationName NVARCHAR(50) NOT NULL,
       LocationCode BIT NOT NULL
);

CREATE TABLE md.TaskInProgress (
       TaskInProgressId INT PRIMARY KEY,
       TaskId INT NOT NULL,
       ItemInputId INT NOT NULL,
       ItemOutputId INT NOT NULL,
       ItemInputQty DECIMAL NOT NULL,
       ItemOutputQty DECIMAL NOT NULL,
       ItemLocationId INT NOT NULL,
);
CREATE TABLE md.Task (
       TaskId INT PRIMARY KEY,
```

```
	TaskName NVARCHAR(70) NOT NULL
);

CREATE TABLE md.Chain (
	ChainId INT PRIMARY KEY,
	ItemId INT unique NOT NULL
);

CREATE TABLE md.ChainNode (
	ChainNodeId INT PRIMARY KEY,
	TaskId INT NOT NULL,
	ParentTaskId INT NOT NULL,
	ChainId INT NOT NULL
);

CREATE TABLE md.[Role] (
	RoleId INT PRIMARY KEY,
	[Role] NVARCHAR(40) NOT NULL,
);

CREATE TABLE md.Employee (
	EmployeeId INT PRIMARY KEY,
	EmployeeName NVARCHAR(50) NOT NULL,
	EmployeeSurname NVARCHAR(50) NOT NULL,
	EmployeeMail NVARCHAR(100) NOT NULL,
	EmployeeLogin NVARCHAR(50) NOT NULL,
	EmployeePassword NVARCHAR(50) NOT NULL,
	EmployeeRoleId INT NOT NULL
);

CREATE TABLE md.Request (
	RequestId INT PRIMARY KEY,
	RequestTypeId INT NOT NULL,
	RequestBody NVARCHAR(MAX) NULL,
	ItemLocationId INT NOT NULL,
	EmployeeId INT NOT NULL
);

CREATE TABLE md.RequestType (
	RequestTypeId INT  PRIMARY KEY,
	RequestType NVARCHAR(40) NOT NULL
);

CREATE TABLE md.Lot (
	LotId INT PRIMARY KEY,
	ItemLocationId INT NOT NULL,
	LotNumber NVARCHAR(40) NOT NULL,
	InventoryQty DECIMAL NOT NULL
);

CREATE TABLE md.Vendor (
	VendorId INT PRIMARY KEY,
	VendorName NVARCHAR(50) NOT NULL,
	VendorMail NVARCHAR(50) NULL,
	VendorAddress NVARCHAR(150) NULL
);

CREATE TABLE md.ShipmentHistory (
	ShipmentHistoryId INT PRIMARY KEY,
	ModifiedData NVARCHAR(MAX) NOT NULL,
	ItemLocationId INT NOT NULL
);
CREATE TABLE md.ReceivingHistory (
```

```
	ReceivingHistoryId INT PRIMARY KEY,
	ModifiedData NVARCHAR(MAX) NOT NULL,
	ItemLocationId INT NOT NULL
);

CREATE TABLE md.TransferringHistory (
	TransferringHistoryId INT PRIMARY KEY,
	ModifiedData NVARCHAR(MAX) NOT NULL,
	ItemLocationId INT NOT NULL
);

/*********************************************************************/
/*_____________________________AlTERING TABLES_____________________________*/
/*********************************************************************/

/***************Item REFERENCES***************/
ALTER TABLE md.Item
ADD CONSTRAINT FK_Item_BOM
	FOREIGN KEY (BomId)
	REFERENCES md.BOM (BomId)
ALTER TABLE md.Item
ADD CONSTRAINT FK_Item_UOM
	FOREIGN KEY (UomId)
	REFERENCES md.UOM (UomId)
/************ItemLocation REFERENCES************/
ALTER TABLE md.ItemLocation
ADD CONSTRAINT FK_Item_ItemLocation
	FOREIGN KEY (ItemId)
	REFERENCES md.Item (ItemId)
ALTER TABLE md.ItemLocation
ADD CONSTRAINT FK_Location_ItemLocation
	FOREIGN KEY (LocationId)
	REFERENCES md.[Location] (LocationId)

/***************Chain REFERENCES***************/
ALTER TABLE md.Chain
ADD CONSTRAINT FK_Chain_Item
	FOREIGN KEY (ItemId)
	REFERENCES md.Item (ItemId)

/*************ChainNode REFERENCES*************/
ALTER TABLE md.ChainNode
ADD CONSTRAINT FK_ChainNode_Chain
	FOREIGN KEY (ChainId)
	REFERENCES md.Chain (ChainId)
ALTER TABLE md.ChainNode
ADD CONSTRAINT FK_ChainNode_Task
	FOREIGN KEY (TaskId)
	REFERENCES md.Task (TaskId)
ALTER TABLE md.ChainNode
ADD CONSTRAINT FK_ChainNode_ParentTask
	FOREIGN KEY (ParentTaskId)
	REFERENCES md.Task (TaskId)

/************TaskInProgress REFERENCES**********/
ALTER TABLE md.TaskInProgress
ADD CONSTRAINT FK_TaskInProgress_Task
	FOREIGN KEY (TaskId)
	REFERENCES md.Task (TaskId)
ALTER TABLE md.TaskInProgress
ADD CONSTRAINT FK_TaskInProgress_ItemLocation
	FOREIGN KEY (ItemLocationId)
```

```
       REFERENCES md.ItemLocation (ItemLocationId)

/**************Employee REFERENCES*************/
ALTER TABLE md.Employee
ADD CONSTRAINT FK_Employee_Role
       FOREIGN KEY (EmployeeRoleId)
       REFERENCES md.[Role] (RoleId)

/**************Request REFERENCES**************/
ALTER TABLE md.Request
ADD CONSTRAINT FK_Request_Employee
       FOREIGN KEY (EmployeeId)
       REFERENCES md.Employee (EmployeeId)
ALTER TABLE md.Request
ADD CONSTRAINT FK_Request_ItemLocation
       FOREIGN KEY (ItemLocationId)
       REFERENCES md.ItemLocation (ItemLocationId)
ALTER TABLE md.Request
ADD CONSTRAINT FK_Request_RequestType
       FOREIGN KEY (RequestTypeId)
       REFERENCES md.RequestType (RequestTypeId)

/****************Lot REFERENCES***************/
ALTER TABLE md.Lot
ADD CONSTRAINT FK_Lot_ItemLocation
       FOREIGN KEY (ItemLocationId)
       REFERENCES md.ItemLocation (ItemLocationId)

/********TransferringHistory REFERENCES*********/
ALTER TABLE md.TransferringHistory
ADD CONSTRAINT FK_TransferringHistory_ItemLocation
       FOREIGN KEY (ItemLocationId)
       REFERENCES md.ItemLocation (ItemLocationId)
/********ReceivingHistory REFERENCES*********/
ALTER TABLE md.ReceivingHistory
ADD CONSTRAINT FK_ReceivingHistory_ItemLocation
       FOREIGN KEY (ItemLocationId)
       REFERENCES md.ItemLocation (ItemLocationId)
/********ShipmentHistory REFERENCES*********/
ALTER TABLE md.ShipmentHistory
ADD CONSTRAINT FK_ShipmentHistory_ItemLocation
       FOREIGN KEY (ItemLocationId)
       REFERENCES md.ItemLocation (ItemLocationId)
```

APPENDIX B

Database diagram