



VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
BRNO UNIVERSITY OF TECHNOLOGY



FAKULTA PODNIKATELSKÁ
ÚSTAV MANAGEMENTU

FACULTY OF BUSINESS AND MANAGEMENT
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VYUŽITÍ DISKRÉTNÍ SIMULACE PŘI ŘÍZENÍ VÝROBNÍHO PROCESU

MANUFACTURING PROCESSES MANAGEMENT WITH USAGE OF SIMULATION TOOLS

DIPLOMOVÁ PRÁCE
MASTER'S THESIS

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BRNO 2011
Brno University of Technology
Faculty of Business and Management

Academic year: 2010/2011
Institute of Management

MASTER'S THESIS ASSIGNMENT

Řičtr Jiří, Bc

Company Management and Economics (6208T097)

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Manufacturing Processes Management with Usage of Simulation Tools

In the Czech language:

Využití diskrétní simulace při řízení výrobního procesu

Instruction:

Introduction

Statement the problem and goal of work

Theoretical background about the problem

Analysis of the problem and current status

Proposals and conditions of application

Improvement analysis and evaluation

Conclusion

Bibliography

Attachments

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The deadline to deliver master's thesis is given by the Schedule of the Academic year 2010/2011.

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Abstract

By optimizing the logistics, production and other systems the simulation can reduce costs and rationalise business processes. By use of discrete simulation in software Witness Power with Ease is in this diploma thesis optimised logistical flow of material in the company Company, s.r.o. The thesis introduces methods and particular phases of creating the model including its validation. The proposal in the diploma work suggests the improvement to lower the costs for the transportation services by 24,400 CZK per month.

Abstrakt

Simulace výrobních procesů pomáhá optimalizovat výrobu, logistiku a další systémy, díky čemuž se snižují náklady a racionalizují se vnitropodnikové procesy. Využitím diskrétní simulace programu Witness Power with Ease se v diplomové práci optimalizuje logistický tok materiálu ve společnosti Company, s.r.o. Práce přibližuje metody a jednotlivé fáze tvorby modelu včetně jeho validace a navrhuje vylepšení, díky kterému by mělo dojít ke snížení nákladů na dopravní služby o 24 400 Kč měsíčně.

Key Words

Simulation, optimization of manufacturing process, logistics, kanban, kaizen, Witness, Visio, modelling, validation

Klíčová slova

Simulace, optimalizace výrobního procesu, logistika, kanban, kaizen, Witness, Visio, modelování, validace

Bibliographic reference

RICHTER, J. *Využití diskrétní simulace při řízení výrobního procesu*. Brno: Vysoké učení technické v Brně, Fakulta podnikatelská, 2011. 76 s. Vedoucí diplomové práce
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V Brně dne 26. května 2011

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Poděkování

Rád bych poděkoval vedoucímu mé diplomové práce Ing. Josefu Šunkovi, Ph.D. za zprostředkování prakticky zaměřeného tématu a cenné rady a připomínky, které zvýšily odbornou kvalitu výsledné práce.

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INTRODUCTION

It can be very challenging to keep competitiveness in today dynamic environment. Companies try to shorten the period of reactions to the customer demands in many different ways. The pull system is logical result of consumer driven markets when the signal comes directly from users. Through the marketing activities and systems the demand comes to the production and it needs to be done as soon as possible.

At this place the modern approaches to the production comes to the scene. Methods as Just-in-time, Kaizen and Lean management are very efficient and broadly accepted in manufacturing corporations.

To proceed with effective changes in run-in processes and activities we need some tool to illustrate what consequences our decisions will have. For this reason are helpful computer simulations which compare the reality with modelled situations. Among those simulations belongs also software Witness Power with Ease 1.0 produced by company Lanner group from the United Kingdom. This program uses discrete simulation to study events and its effects during the run of simulation.

Company Company, s.r.o. produces lights for cars and its complex production includes hi-tech assembly lines and other state-of-the-art machines. The most vulnerable bottleneck is seen in logistics which is managed by small carts operated by people. By using simulation tools we will try to find crucial bottlenecks and optimise material flow to reduce costs.

Using simulation software is appropriate mostly for mid-size and large companies due to high purchase costs and necessity to hire professionals or to train own employees. The second mentioned option is long termed and is useful for ongoing and complex optimising process which is probably the right one for the analysed firm.

1 STATEMENT THE PROBLEM AND GOAL OF WORK

Company COMPANY 1, s.r.o. located in Town is focused on producing lights for cars and vans. Its inner production system is based on pull principle and thus the delivery of material happens on the signals coming from assembly line.

The analysed segment in the company is the assembly line where the lights for Brand Car are made. Into this line is brought about 20 different pieces to assemble one final product. The transportations of these parts are outsourced by external company Outsourcing company , s.r.o. The material is physically moved by several carriers which each of them follows specific rules and logic. In the diploma work is done the analysis of inner logistics, it is created model and performed the simulation on which basis are suggested proposals for more efficient production.

The simulation should be the springboard for more complex modelling and optimising of the material flow inside the factory in later stages.

The main goal of the work is **reducing the costs** of the inner logistic. This goal can be achieved by simulation tools which is the main topic of this thesis. Subsidiary goals which will help to fulfil this main goal are following:

Subsidiary goals of the work:

- *Analyze the situation and collect all necessary information (this also helps the company to realize what data are kept and which of them are useful and which are not recorded sufficiently)*
- *Creation of a model which can be used also later for other optimising activities*
- *To propose more efficient setup of logistic with use of Simulation software (costs reduction –human and equipment resources, time savings, detect risks etc.)*
- *Get the outside look at the logistics and bring fresh ideas how to manage it*
- *Show the advantages of using Witness Simulation Software*

2 THEORETICAL BACKGROUND ABOUT THE PROBLEM

2.1 Business processes

Business process is set of activities which demands one or more inputs and produces an output with a value for the customer. The result of these periodically repeating actions is the delivery of product directly to customer. Process consists of single actions (elements). Process approach in company is visible through all business and is connected with non-producing departments, too. Information support can be found in these areas: SCM (Supply Chain Management), CRM (Customer relationship management) and e-business. (5)

Link between business processes and information systems is very tight. Outcome of implementing business information systems is better accessibility of data sets and to improve production processes. (3)

For each company and its sustainability on the market is necessary to improve individually single business processes. Customers demand better products and services so many firms begin to work with their inner processes. We need to map processes and document them and analyse, verify and measure frequency of change.

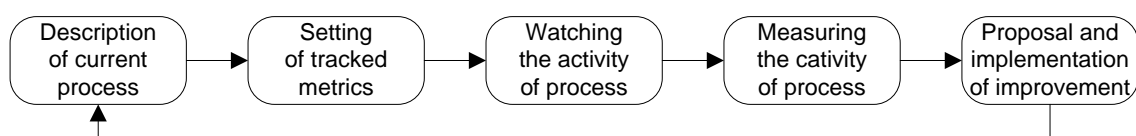


Chart 1: Improving of processes.

There are different kinds of processes:

- **Key process** – main process which fulfil the mission of company. It is a place where main added value for the customer is created. It is represented by sequence of activities coming from customer requirement to his satisfaction.

- **Supporting process** – ensures the product to inner customer or key process. Thought this product can be obtained externally without endangering the mission of company, it is made internally for the economic purposes or to reduce a risk.
- **Secondary process** – is executed within the company for the economic purposes. (10)

Controlling processes are another group of processes. In practise it is used a method CMM (Capability Maturity Model) which separates processes according to their maturity:

- **Non-existing** – company have not recognized the problem yet
- **Random** – company finds out the problems and wants to solve them
- **Repeated (only intuitive)** – effort to create standard processes but they are used solely intuitively
- **Formalized** - employees are trained for the standardized processes
- **Measurable** – controlling process is added for continuous improvements
- **Optimised** – processes were developed to the best possible state (1)

2.2 Production management systems

We recognize two main approaches in production management. Term push and pull is widely used in logistics and SCM but it can be also found in marketing. Push-pull system describes flow of product and information between two objects in company. In customer markets the goods or information are “pulled” by customers, while manufacturers and suppliers “push” the goods to the market. (9)

2.2.1 Push system

In push system the production is realized according to production plan and availability of material which force an order through the production process. Another meaning of

push strategy in marketing can be found in communication between seller and buyer. According to used information the communication can be interactive or non-interactive. For example, if the seller uses TV or radio for promotion, the interaction is not possible. On the other side, the customer can interact with seller when the message is broadened by internet or phone call. In the first case, the information is pushed to buyer, while in second example it is possible to buyer to demand necessary information according to his requirements.

Signs of push system:

- *is used for the part of supply chain in which the demand is insecure and relatively small*
- *production and distribution is based on long term prognoses*
- *inability to satisfy changing structure of demand*
- *unacceptable levels of services*
- *excessive inventory according to the need of safety reserves*
- *smaller expenses to promotion*

This principle is used in methods MRP and MRS where determines terms and dates to order material according to structure of production plan.

2.2.2 Pull system

In this system the customer demands a product and pulls it via offered channel. Example can be found in company Ford Australia. Ford Australia produces only cars which were order by customers in advance – tailor made. The ones who decide what will be produced and when, are customers. Ideal model is when the number of goods is the same as demanded amount by consumers. It is market aimed approach to production. KANBAN and JIT (Just-in-time) principles belong to this system. It is a key tool used in pull manufacturing system. In tight connection with pull manufacturing system is also lean manufacturing, which helps to remove wasting during a production process.

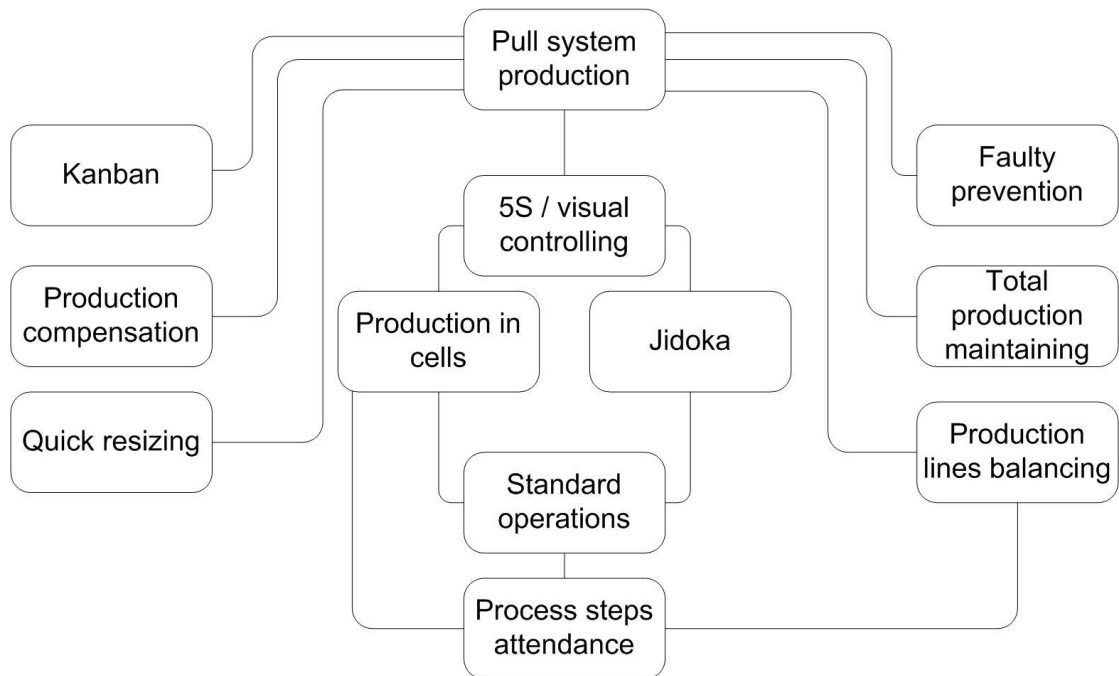


Chart 2: Related methods in lean manufacturing.

- **5S** – focuses on wasting caused by mess on workplace, e. g. chucked or missing tools which does not have their keeping place, badly marked material and parts, overfull storage areas and corridors.
- **TPM** – deals with lost time and costs during unplanned shutdowns
- **Kanban** – helps to reduce overproduction and production-in-progress
- **Quick resizing** – focuses on reducing the time necessary to change the setting of production machinery time
- **Faulty prevention** – removes lost time and costs linked with wrong procedures
- **Standardization** – determines standard procedures for each manufacturing operation and supervise its complying with standards and improving of single processes
- **Jidoka** – or so-called “human automation” is a process which provides an option for the workmen to stop the manufacturing line whenever they find faulty performance, so they can remove this shortcomings
- **Production lines balancing** – shifting the workmen to a production line where the largest production is¹

¹ PRODUCTIVITY PRESS DEVELOPMENT TEAM: *Kanban for the Shopfloor*. Productivity Press. 2002. 120 p .ISBN 978-1563272691

The only way to shorten the production time is the method of lean manufacturing. Switch-over to pull system influences the information flow and finally it will have the impact also to a production plan.

Pull vs. Push system

The pull system removes wasting of material which comes from push system production where accessible material is pushed from beginning to the end of production programme. In push system accessibility of raw material is the starting point for beginning of the production and buying of material is based on forecasts from last periods. This system results in overproducing and delay of delivery. Material cumulates in stocks and on every critical point. Bottlenecks appear on the places where the production has different cycle than preceding production.

Push and pull systems determine quantity of production, sales and define on which basis the decisions will be made. The main difference is the subject which analyse the market and which decides what amount of goods will be delivered to the customers. Important aspect in this decision process is information.

JIT is typical representative of pull system and MRP II of push system. TOC (Theory of Constraints) as the newest method, combine both principles where the generic points are bottlenecks.

2.3 Modern approaches to production management

To eliminate inefficiency in earlier used systems there were developed new concepts of production which comes out from certain principles and approaches to production management. Aim of these new concepts is to remove absence of strategic thinking in production management, use of old-fashioned procedures and remove insufficient support of production by information technologies.

2.3.1 MRP and MRP II (Material Requirement Planning)

MRP is concept developed in early sixties in USA. Originally it was more focused on material stock control than on production planning. This model replaced generally used control based on norms and introduced direct material ordering according to real stock level. The dispensable inventory is also included in the planning. Calculation of MRP is quite simple and today they are implemented in software for production planning. In almost every cases when this system is used the costs to keep the stock level decrease. The disadvantage is that the planning is based on information from rough production distribution. (4)

The main features of MRP are:

- ***Focus on product*** – comes from calculation based on structure of the product determined by material items necessary for the product.
- ***Focus on future*** – instead of statistical data it uses basic information in files and expected demand.
- ***Complying with demand in time*** – into the account are included also running times of orders apart material items' requirements.
- ***Complying with priorities*** – with regard to customer needs and production plan.

(1)

Calculation of material needs in MRP

By use of piece list, warehouse stock level and production plan defines material needs. It sets the proposals for purchase of material and production orders of pieces. Calculation basis is the value of customer requirements or market prognoses determined for the highest item in piece list within the production plan. Afterwards it is lowered by stock level and expected material arrivals.

Production plan needs

+ allocations

- expected stock level

- expected material arrivals (realized orders)

= net material requirements, purchase or production orders

The main issue with MRP systems is data integrity. If there are some faults in data as for example in piece list or in production plan (MPS – master production schedule) then output data will be wrong, too (GIGO – Garbage in, garbage out). Most of the sellers of these systems recommends at least 99% data integrity to get useful results. Another problem of MRP systems is to determine how long it will take to manufacture a product from the pieces (when all of them are accessible). Last not least there have to be trainings for great amount of employees to use this system.

Method MRP plans orders regarding to minimal stock level and necessary time which leads to cutting the financial resources. It can be applied to items which are bought from suppliers as well as to configurations which are parts of more complex subjects.

Requirement to correlate earlier mentioned methods (MRP, CRP, MPS and feedback) leads to new system called MRP II which is connected to trade and purchase plan as well as to financial analyses.

In the seventies new system called MRP II arose by improving MRP. The new method had detailed production schedule which had tighter connection with material orders and capacity calculations. The main advantage was the expressive cut-down of floating capital fixture, cost savings to acquire and keep inventory.

2.3.2 TOC (Theory of Constraint)

Theory of Constraint is overall management philosophy introduced by Dr. Eliyahu M. Goldratt in his book called The Goal in 1984, where he focuses on helping organisations to reach their goals. The name comes from the fact that whatever system is limited to

reaching its goal by small amount of constraints and there is always at least one of them. The main assumption of the theory is each organisation can be measured and managed by three scales: transmittance, operating costs and inventory level. Transmittance is the money (or unit aims) which comes from sales. Inventory level is money invested to system to sell its goods and services. Operating costs are all the money which the system spends to transmit the inventory. Process TOC tries to identify the constraint and restructure the rest of organisation by using following five steps:

1. *Identify the constraint (the resource or policy that prevents the organization from obtaining more of the goal)*
2. *Decide how to exploit the constraint (get the most capacity out of the constrained process)*
3. *Subordinate all other processes to above decision (align the whole system or organization to support the decision made above)*
4. *Elevate the constraint (make other major changes needed to break the constraint)*
5. *If, as a result of these steps, the constraint has moved, return to Step 1. Don't let inertia become the constraint. (2)*

These five steps should ensure continual improving of the constraints in organisation. In literature is TOC mentioned as “process of continuous improving” (POOGI). These steps are crucial to develop specific applications mentioned below.

A constraint is anything that prevents the system from achieving more of its goal. There are many ways that constraints can show up, but a core principle within TOC is that there are not tens or hundreds of constraints. There is at least one and at most a few in any given system. Constraints can be internal or external to the system. An internal constraint is in evidence when the market demands more from the system than it can deliver. If this is the case, then the focus of the organization should be on discovering that constraint and following the five focusing steps to open it up (and potentially remove it). An external constraint exists when the system can produce more than the

market will bear. If this is the case, then the organization should focus on mechanisms to create more demand for its products or services. (12)

Part of TOC is OPT (Optimised Production Technology) which is method of scheduling dictates that material should only be launched on to the shop floor at the rate at which it is consumed by the bottleneck. The aim of OPT is to schedule bottleneck capacity in an efficient way. This schedule is the master for the demand placed on other capacities.

The main features of OPT are:

- *Balance flow not capacity.*
- *The level of utilization of any part of the system, which is not a bottleneck, is dependent on other constraints in the system, not the potential of the worker.*
- *The utilization and activation of a resource are not synonymous.*
- *An hour lost at the bottleneck is an hour lost for the total system.*
- *An hour saved at a non-bottleneck is just a mirage.*
- *Bottlenecks govern both throughput and inventories.*
- *The transfer batch may not, and many times should not be equal to the process batch.*
- *The process batch should be variable, not fixed. (14)*

Executives of OPT are planning modules. OPT is based on two phases. In the first phase the preliminary planning is going retroactively. The goal of this phase is to find bottlenecks and identify critical and uncritical manufacturing resources. In the next phase – final planning – is planned via forward schedule.

2.3.3 JIT (Just-in-time) and Kanban

Just-in-time is a strategy which pursues the improving of investment return by reducing the semi finished material and related operating costs. JUT is focused on material flow fluency. They are reduced running times of produce by minimising the idle times and by type casting of the machine. The variable size of manufacturing batches is used. To fulfil the aim of JIT the process uses a Kanban system. According to this system it is

possible to divide the production to “seller” and “buyer” who sends the label (Kanban) with order. The seller reacts by supplying demanded product to the buyer. The method requires single-direction material flow and synchronization of operations. (1) Kanban system, if used properly, can improve investment return, quality and efficiency of the manufacturing company.

Philosophy of JIT is simple and is oriented to eliminate 5 basic kinds of losses: coming from overproduction, idling, transport, keeping the stock level and poor quality products. Briefly speaking, just-in-time system is focused to have material on proper place, in proper time and in proper quantity without need of keeping the safety stock. System JIT is typical for cost strategies:

- *Keeps stock holding costs to a bare minimum*
- *Works on a demand-pull basis*
- *Reduces lead times and uses frequent deliveries with minimized lot sizes*
- *Reduces set up times*
- *Minimises motion waste by shortening the distance among workplaces*
- *Makes production simple and transparent*
- *Supports motivation of staff at all levels of the organization*
- *Avoids to manufacture a thing which can be bought for cheaper (4)*

As a result the JIT can bring reduced stock level and semi-finished production, smaller and more efficient storage areas, shorter through and set-up times, higher efficiency a usage of workplaces and machines, lowering of overhead costs and increased quality. On the other side implementation of JIT is highly sophisticatedly expensive and time-consuming.

Lean management

Lean management (sometimes just “Lean”) is manufacturing process which identifies all non-value adding actions for final customer as wasting and which distracts the company from achieving its goal. Lean manufacturing is similar to concept of efficiency

based on flow optimisation. People are solving the problem of inefficiency and wasting during the history by empiric methods and they try to decide what the crucial point is. Lean manufacturing is usually seen as softer version of older attempts which can take up to work of leaders as Taylor or Ford and to avoid their mistakes. (4)

2.3.4 KAIZEN

Kaizen method comes from Japan and means improvement apart that it is one of the most used words there. Kaizen refers to philosophy or processes of continual improvement in production, engineering and business processes and control support. Kaizen focus to improve activities in every aspect of business. It contains all functions and processes as purchasing department, logistics and SCM and has impact on all levels of staff from CEO to workers on production lines. This method is used widely across the world. Kaizen contains several crucial practices:

- Focus to customers
- Total quality management and quality improvement
- Robotics of automation
- Quality circles
- System of improvement suggestions
- Discipline on the working place and absolute maintenance of production facilities
- Just-in-time and Kanban
- No flaw goods
- Good relationships with customer on all lines
- New products development
- Teamwork (7)

5 steps of Kaizen

1. *Sorting (**Seiri**) - Eliminate all unnecessary tools, parts, and instructions. Everything else is stored or discarded. Essential items keep in easily-accessible places.*
2. *Straightening or setting in order / stabilize (**Seiton**) - There should be a place for everything and everything should be in its place. The place for each item should be clearly labelled or demarcated. Items should be arranged in a manner that promotes efficient work flow.*
3. *Sweeping or shining or cleanliness / systematic cleaning (**Seiso**) - Keep the workplace tidy and organized. A key point is that maintaining cleanliness should be part of the daily work – not an occasional activity initiated when things get too messy.*
4. *Standardizing (**Seiketsu**) - Work practices should be consistent and standardized. All work stations for a particular job should be identical. Everyone should know exactly what his or her responsibilities are for adhering to the first 3 S's.*
5. *Sustaining the discipline or self-discipline (**Shitsuke**) - Maintain and review standards and do not allow a gradual decline back to the old ways. While thinking about the new way, also be thinking about yet better ways.*

Kaizen represents humane approach because it assumes that all workers will join to cooperate. It is based on idea that every labourer can contribute to improvement of system. Strategy is paying attention to process as well as to result.

2.4 Process modelling

Nowadays it is not quite possible to describe real systems because of their extensiveness and complex inside and outside connections and also because of external effects which are difficult to predict. One of the tools to study these systems is modelling which

simplify the reality to essential factors with greatest impacts. The aim is determined in the first steps during the real system modelling, in other words it is set the problem which has to be solved. By modelling we mean creating of model. (8)

Types of models

In fact of wide range and complexity of real objects we need to decide which kind of model we will use. There are several options and points of view how to divide them.

Following image shows the division according to J. Daněk: (16)

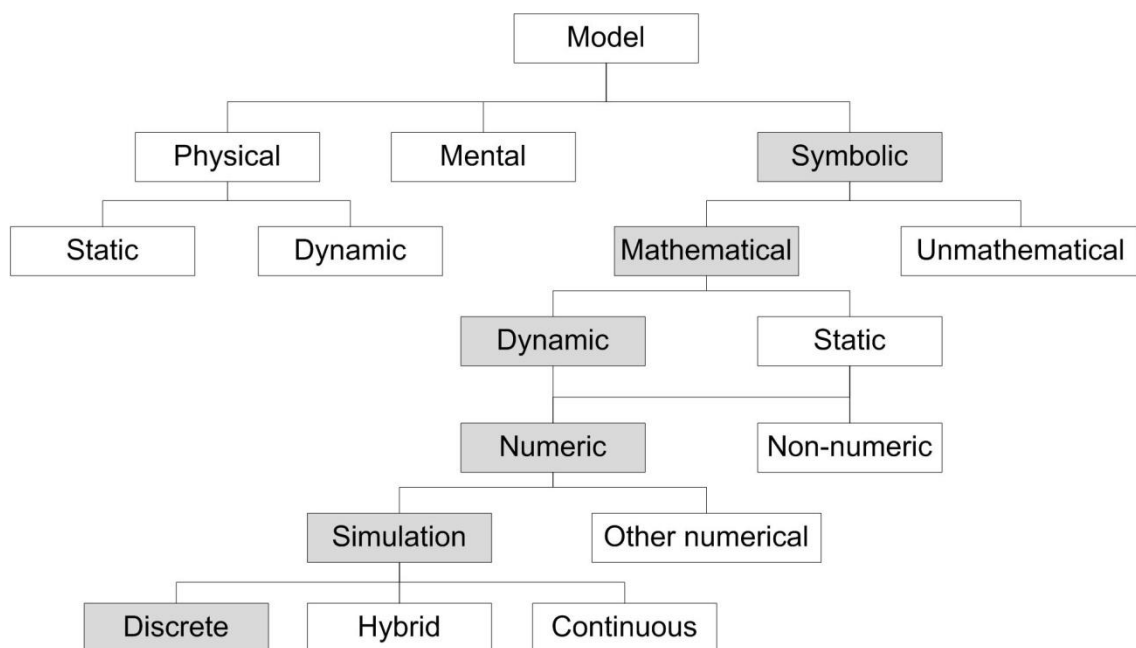


Chart 3: Types of models by J. Daněk.

Models are useful in many economic areas and suitable to solve wide range of problems. Discrete event models are usually used for real operations. Via them it is possible to coordinate demands of different workplaces, reduce operational costs, improve material flow through assembly line etc. These models or by simulation modified version of them provide detailed statistical processes. They are useful on lower management levels, for example at production process control. On strategic level they are not used so much because of their in-depth, detailed and focus on one process character. It is not possible to provide efficient overlook of business as a whole.

Continuous or real-time simulations are contrary used on aggregate level what means they represents their states and changes in time. As example of aggregated state can be business performance. In practice this models are used as tools to support strategic decisions, marketing plans and to elaborate business plan. (23)

2.5 Simulation

Simulation software is widely used in many areas of human existence and it became the part of scientific and common practices. Together with increasing technology and programme resources the simulation allows to process through complex calculations and experiments which is currently one of the most important methods how to acquire new findings.

Simulation models provide information about probable consequences of alternative decisions. Its use is appropriate mostly in case we follow more goals. (15) The most usage of simulation is nowadays in technical areas such as mechanical and electrical engineering and in chemistry.

2.5.1 Discrete event simulation

Discrete event simulations are characterized by step discontinuous variables which change only if some event occurred. They is used next-event technique (model changes only when event is realized) to control the behaviour of model.

Model (simplification of reality) which is base of simulation contains chronological continuous actions. Due to results obtained from simulation we can find out behaving of complex dynamic system which is changing in time under various conditions.

Discrete event simulation uses some typical discrete items which represents every discrete system.

- **Clock** – according to set units (hours, minutes, seconds) the time changes instantaneously.
- **Events list** – changes in the simulation system. They can be expressed by change of entity state and time when the change occurred.
- **Random-Number Generators** – to generate numbers they are pseudorandom number generators in use. Their aim is to imitate reality, for example when customers come during different times and in different amount.
- **Statistics** – The result of simulation are statistical data gained during the simulation which we need to process and analyze to get the proper information.
- **Ending Conditions** – the simulation would be never-ending without ending conditions. They can be for example 20 repetitions or 5 shifts in shop floor.

2.5.2 Phases of computer simulation production

The aim of simulation projects is business processes improving (higher efficiency, lower costs, etc.). The production passes through certain phases which are not always obligatory and strict.

Skip or underestimation can save time and money but more often it ends with higher price of project. There are many ways how to classify phases and steps of the project but in general we can speak about following scheme:

PHASE 1 Problem recognition and aim determination

Proper definition of problem is essential for success. It is common that even good managers are not able to determine the cause of problem from the beginning. It is crucial in this moment to arrange meeting between client and research team.

PHASE 2 Conceptual model creation

Before the computer model is made it is necessary to make a basic conception about modelling system. Entry data are:

- *What business we simulate and who are the customers*
- *Efficiency criteria determination*

- *Level of profundity determination*
- *What objects are present in system*
- *What requests and demands entry the system*
- *How are the sources allocated*

To be capable to create a production systems model and included processes it is essential to comprehend the structure of manufacture and to get know its sections:

- *Type of manufacture*
- *Topology and lay-out*
- *Material flow*
- *Information flow*
- *Machinery and equipment*
- *Staff and HR*

PHASE 3 Data gathering

Simulation is very demanding for data. The problem occurs when they are not disposable. It is possible to create the model without data if there are sufficient alternative prerequisites (expert's testimony, analogy, etc.). Another option is to listen to the people from shop floor that have the most experience.

PHASE 4 Simulation model creating

Simulation model comes out from conceptual model (Phase 2). Creating of computer model is the first checkpoint of conceptual model because computer's logic discloses the issues which were omitted.

PHASE 5 Verification and validation

By verification we mean verifying if the model is accordance with conceptual model. It is a check-up of transform from real world to the simulation programme. Validation stands for revising if the model is in compliance with reality. The best way how to prove it is to compare data output from the model with real data. There will never be

complete conformity between both systems and it is appropriate to avoid over detailed models which are difficult to run. There can be three types of validity:

- *replicate validity* - reproduce data from real world
- *predictive validity* – model outputs data before the real world
- *structural validity* – model is able to reproduce observed data and it also reflects the way of actions in reality

PHASE 6 Experimenting and results analyses

In this stage the model brings first results what is very rewarding for the research team. It is recommended to begin a discussion about the functionality of model and how to hand the results to the client. It is convenient to prepare several alternatives to discuss.

PHASE 7 Documentation

Often is this phase underestimated which makes it very difficult to return for the created model later and use it again. It is necessary to describe the structure, development of the model and gained results to keep it understandable for other users.

PHASE 8 Implementation

The last phase is very important because if we do not implement the simulated model, all the effort will have no effect and it will be just a waste of resources. Sometimes there is a problem with staff who does not want to accept proposed changes. (11)

3 ANALYSIS OF THE PROBLEM AND CURRENT STATUS

3.1 Company review

COMPANY is a Germany based company producing lights for passenger and goods vehicles.

3.1.1 Company structure

Company Regional center, s.r.o. is hundred-per-cent owner of *COMPANY, s.r.o.*, *COMPANY 1, s.r.o.* and *COMPANY CZ, s.r.o.* At the same time *Company Regional center, s.r.o.* (found in 2099) is subsidiary of *Reinhold Poersch GmbH* from Lippstadt, Germany.

COMPANY 1, s.r.o. focuses mainly on production, while COMPANY, s.r.o. is focused on research, development, measuring and testing. These two firms are based in Town as Company group Town. COMPANY CZ, s.r.o. takes care about spare parts sales and support for customers. And Company Regional center, s.r.o., based in Town 2, supports subsidiaries with IT services, buying services, etc. (19)

COMPANY, s.r.o.

Name:	COMPANY, s.r.o.
ID:	99999999
Date registry to the Company Register:	99999999 1992
Residence:	99999999
	Legal form: Limited liability Company
Statutory body:	999999
Fixed capital:	CZK 9999999

COMPANY 1, s.r.o.

Name:	COMPANY 1, s.r.o.
ID:	99999
Date registry to the Company Register:	999 1999

Residence: 9999999
9999999999

Legal form: Limited liability Company

Subject of Enterprise:

Statutory body: 9999999

Fixed capital: CZK 999999

At first COMPANY 1 produced only limited types of lights but as cooperation continued in good way, the mother company decided to broaden the production. Nowadays COMPANY 1 produces more than 99 different types of lights, each with many variants (for EU/US market, left driving countries etc.).

3.1.2 Products

Thanks to very high quality and obtained certifications, COMPANY 1 makes lights for high pitch car brands as **Tatra, Tatra, Tatra, Tatra, Tatra** etc.

3.1.3 Economic data

Company group Town made in 2010 revenues of **9999,000 CZK** (increase by CC.79% compared to year 2009) and profit of about **9999,000 CZK** (from **9999,000 CZK** in 2009, **999%** decrease).

Thousands of CZK	2008	2009	2010
Revenues	1234	1234	1234
Profit	1234	1234	1234

Table 1: Revenues and profit decrease during financial crisis and its return. (Own structure. Source: EMIS: COMPANY 1, s.r.o. | Česká republika. [online]. 2011 [cit. 2011-05-21].)

In August 2010 the company employed **9999 employees** (21) which is about 100 more than during the financial crises when the company had to dismiss about 300 people. (22) According to financial data and employee statistics it seems the crises was already surpassed. Company group Town obtained many awards during its business activity, for example it was one of 100 most admired companies in Czech Republic. (18)

3.2 *Production in COMPANY 1, s.r.o.*

In COMPANY 1, s.r.o. in Town there are 9 different **production lines**² [Attachment 1]. On each line there is defined a project. **Project** means what kind of light is produced (for what car). At a time there is produced only one type of light. Every time we need to produce different type, we must change the project and the assembly line has to be adjusted. This can take about 99 days.

Each type of light can be made in several variations. **Variations** can be Right-handed lights, Left-handed lights, variations according to different export markets (American market has other specifications than EU's).

Our analysed line has identification number **9999**. The current project on the line is **Brand Car** lights. Currently there are produced four variations (for right-handed and left-handed traffic and lights for left and right side of a car).

There is a **multi-shift** operation in COMPANY 1:

- Morning shift – 6⁰⁰ – 14⁰⁰
- Day shift – 14⁰⁰ - 22⁰⁰
- Night shift – 22⁰⁰ - 6⁰⁰

3.2.1 **Technology**

In COMPANY 1, s.r.o. there are used state-of-the-art transportation technologies, information systems, reading devices etc.

Milk-run carts

The parts are delivered from the central stock to the assembly line by carts operated by cart-men. Each cart has its defined route and always serves more than one assembly line. These carts are figuratively called **milk-runs** as from a real word, where they serve every day the same route.

Image 1 Milk-run cart during handle of assembly line. (Own picture)

² Each line is specified by 4-digit identification number

The capacity of cart is extendable by joining another trailer in stock.

Storage vehicles

High-lift trucks and additional trolleys are used to operate the material right in the stock. The transportation from the stock to the production line is entirely in charge of Milk-run carts.

Storage racks

The parts and material are stored at different kinds of racks. For bigger parts are used multi-storeys pallet racks, for smaller parts which can be hardly to find in large areas are used specialized automated selective racks called **Kardex**.

Reading devices

Every box with parts has its unique identify number labelled by barcode. This barcode is named **e-Kanban** and is represented by label in the shel. These codes are readable by electronic devices and wirelessly transferred to the central database.

3.2.2 Provided data

Piece List

Each final product – light - is composed of many small parts. Some of the parts are prefabricated in COMPANY 1, s.r.o. in Town and some other are **outsourced** from company Company from Town 3.

In analysed line 9999 there are 9 different variations³ of lights produced:

- **111.111-1** – left light for right-hand traffic
- **111.111-2** – right light for right-hand traffic
- 111.111-3 – left light for left-hand traffic
- 11.111-4 – right light for left-hand traffic

Each variation is made of slightly different parts. We will deal with first two variations only. In the first file [Attachment 3] there is piece list which defines what parts are used, in what amount and in which succession.

.

³ Different variations of model are characterized by last three digits in ID number.

Every variation is made of 99 pieces. However some of the parts are already prefabricated in other places in factory or are outsourced. So in fact in assembly line 9999 there are used only 9 prefabricated parts. In this amount also additional material is included (labels, plastic foil, wrapping etc.). This material is delivered ad-hoc when it is necessary because of its very low turnover rate.

As mentioned earlier, there are two material flows, one of bigger parts and other of small parts.

Our final product is made of 6 big parts which are packed in Rollboxes [Attachment 3]. These pieces are unique for each Variation. In the parenthesis there is stated the number of pieces in one box:

The Rollboxes are brought by operator who supplies only **one assembly** line.

On the other side the small parts are the same for variations 247.051-017 and 247.051-027 (plus some of them are used more times in one light). There are 11 small pieces for each type of light. The amount of parts in one box is mentioned in parenthesis again.

These parts are brought by different operator who supplies also **other lines** (see below). Note the parts 99999-01 and 02 which are unique for each variation but are delivered by Kardex-ers. It is because this part is a light bulb which is stored in locked shelves near Kardex racks and the operators need to have proper authorisation to access them.

Timing data

Every time the operator comes to the Supermarket where the empty place is for the part, he uses his reading device to read the barcode. The code is transferred to central information system and stored there. These are the basic information which we will use to create our model.

We have available data set for the period of four weeks (04/12/10 – 05/02/10). First file contains data about parts brought to the line [Attachment 4] and second about how many final lights were carried away from the line to the central stock [Attachment 5].

Both data sets have the same structure:

All the titles seem to be obvious. Crucial columns are. Other titles are useless for our model.

3.2.3 Material flow

In Company the in-house logistic is outsourced by external company **Outsourcing company s.r.o.** which is in charge of managing delivering the material and uses other related services (ordering IS, controlling the machinery etc.)

Each production line is supplied with material (parts) from **central** and **external stock** (). [Attachment 1] Each line possesses its own area (called **Supermarket, Kanban** or **Pull area**) where parts are laid for prompt usage. Every line has its own master (line handler), who coordinates material flow right in the production line and pulls it manually from Supermarket to the destination workplace.

The material is packed in boxes with different capacity and it is essential to distinguish two different material flows, because each group follows different schedule and route:

- ***Small parts** – high capacity boxes (999 pieces per box) – operators are nicknamed **KARDEXers** (actually the name of storage racks for small pieces) and every operator supplies between 9 lines.*
- ***Big parts** – lower capacity boxes (99) – these boxes are called Rollboxes and operators simply **delivery men**. Every delivery man attends to one assembly line only.*

(In the next chapter this topic will be explained in more detail.)

The logistical supply system used in factory is **PULL production** (stated in the part Theoretical basis). That is why we begin to describe the material flow with final operation - assembly of light and its transportation to the stock. In the next step we will see how the pull system demands other pieces and how this situation is covered.

Still it is essential to distinguish two separate material flows. When the amount of packs in Supermarket sinks under certain level:

- *the Milk-run operator brings other packs from the **central stock** in amount based),*
- *the line handler orders parts from **external stock** or **other area** and*

Empty places are clearly visible due to Kanban system.

3.3 Final products and empty boxes flow

The assembly line produces final parts which are packed to rolls by **99 pieces**. During one machine cycle - **59 seconds** – the machine produces one light of each variation – 99999-01 and 99999-02. That makes two different rolls every 99 min or so.

3.3.1 Logic of flow

The final parts delivery man is in charge of only these rolls and he takes them to the stock for **later expedition**.

3.3.2 Time analyses

Following time data were found out from observing and measuring of the delivery man activities:

- *The way to the assembly line – 9 min*
- *The way to Stock –9 min*

3.4 Small parts flow

As mentioned earlier smaller parts are operated by so-called Kardex operators. According to analysis [Attachment 2] the Kardex-ers supply following

Table 2: Production lines supplied by KARDEX operator. [Own construction]

We can see that our analysed line **9999** is handled with 9 or 9 other lines by one person.

The operators supplying lines are identified by these names:

3.4.1 Logic of flow

Logic scheme is key element when analysing logistics. The small parts are brought
The initial process in the chart is accepting the **order** of final product.

There is also a backup possibility.

3.4.2 Supermarket Capacities

The capacity determines how many boxes can be kept in Supermarket shelves.

For the following parts the capacities are **9 boxes**:

9999

For the light bulbs 9999_1 and 9999_1 the capacity is **9 boxes** for each. The headlamps are stored in six packages for each variation.

For the **empty boxes** is prepared 9 Rollers which are transported when is full.

3.4.3 Time analyses

Since we have understood the logic of material and information flow we need to focus on timing of each process in model.

The metering was undertaken directly on workplace by using the regular **chronometers** and also by **interviewing** the operators and delivery men. The times were **averaged** from several measuring. The small parts have following times during the processes:

- *The way to the stock – 9 min*
- *The way from stock to Assembly line – 9 min*

These data are used later in the model.

3.5 Big parts flow

The big parts flow is little bit different than the small parts flow.

3.5.1 Logic of flow

The big parts are prefabricated in manufactory at least 9 days in advance before the final assembly. Meanwhile they are not used they are stored in two possible places:

- *Most of the parts are stored in external stock called **Stock**, which is located across the street.*

- *The situation is different for the part 99999 and 02 variation. These prefabricates are kept in a **other area** which is located according to operating decision somewhere in the workshop*

The **capacity** of Supermarkets is **99 rollers** for all parts except the parts 999-01 and 02. For those two parts the capacity is just **9 rolls**.

On the following picture is shown the logical flow of information and material:

Because the delivery from external stock takes from **99 min** to **99 hours** at most, the delivery man usually do other works in the stock. For the model we did not examined more deeply what the actual works are.

3.5.2 Time analyses

The logistic of big parts has also some specific rules to be respected. When ordering the parts from external stock, the delivery takes approximately **99 min**. Thus the assembly line needs to have enough stockpiles to manage this period. The times for each process are mentioned bellow.

For the parts 171.223-01 and 02 which are brought from Remote pull area:

- ***The way to Remote Pull Area – 9min***
- ***The way to the assembly line – 9 min***

For the rest of the parts brought from Stock:

- ***The way to Intake – 9 min***
- ***The way to Assembly line - 9 min***

4 PROPOSALS AND CONDITIONS OF APPLICATION

Before proceeding to the process modelling we need to clarify what is the aim of the model and which **simplifications** we can use.

4.1 Simplifications

For the optimisation we need to **track** and **examine the activities** of each delivery carts and record their **activity states**. Thus the carts should be set and timed as properly as possible. On the other side, we can reduce the physical side of the model and some other characteristics:

- *The assembly line is just a **Black Box** which pulls parts according to time scheme based on finale machine cycle. No line handler is visualised.*
- *The next assembly line is created only **virtually**. It demands parts **randomly** according to set normal distribution which is close to averaged value of first line 9999 demand. The normal distribution has mean value set to 3 and standard deviation set to 1.*
- *The delivery from Stock is **simplified** by the time which is necessary to bring parts from external stock. This time is around **99 min**. No other aspects are included.*
- *The physical side of the workshop and **logistical tracks** are **simplified** and do not correspondent with reality. That is why it is impossible to investigate and optimise the rides of carts and to find bottlenecks where the risk for the collision is. Deeper modelling and complexity would be needed to comprehend this feature.*
- *The times are **approximated** from measured times and can be sometimes different from reality where many other aspects interfere with the process. That is why it is added normal distribution to all processes.*
- *In the model are shifts set as **continuous flow** during the first **10 shifts**. This is divergent than the reality where the demand determines how many shifts will take place in a week. Sometimes the line can be inactive for several days. This is the reason why the line is filled from the start-up **empty state** just **once**.*

4.2 Creating the model

The model was created by software Witness Power with Ease 1.0. In the model are used several elements to realistically describe what is happening in the workshop:

- **Machines** – primarily are used to assembly final product out of parts which are necessary. The secondary use of machine is for packing and unpacking parts to the and out of rollers to preserve the transportation logistic.
- **Buffers** – are used to contain parts before other process. They can represent pull rows, Kardex racks, Supermarkets in the production line etc.
- **Vehicles** – are the carriers of the parts. They are the main elements in this simulation because they are used for the optimisation. They can be adjusted for several conditions by using the inner code language.
- **Tracks** – are agents which broker the transportation of material by vehicles.
- **Variables** – ensures the logical functionality and statistical records.
- **Charts** – are used to capture the states of the vehicles for later analyses.

4.2.1 Layout of the model

The basic layout of the model is visualised on the screenshot [Attachment 8].

Left side of the model

On the left side are shown different types of stocks:

- For the big parts **Stock**
- For the small parts **Kardex racks**.
- For the final parts **Expedition**.

Each rectangle signifies one part's storage area. The **parts** are named with **numbers** and a **letter P** on the beginning. It is because the Witness needs to put names beginning with letter. Also the dots are forbidden so they are replaced by **underscores**. In the rectangle is written **how many parts** are in a box and **how many boxes** are in the stock. The volume of boxes is set to be enough for 10 consecutive shifts.

Right side of the model

On the right side are shown the **assembly line** together with **Supermarkets** and **Pull areas** located directly next to the line.

For the big parts there are prepared **rows** for each type. They are located behind the assembly line and when the delivery man brings new parts, he pushes them from the farther side --- method is secured.

The small parts are stored in the racks so they occupy very little room. Each shelf has the label which means what part belongs to the exact place (--).

In this section are showed also information about **empty places**, so it is clearly visible how many of them --- **capacity** of place. Also information about the **number of parts** in a box is included.

Middle side of the model

Between the left side (stocks) and right side (assembly line with supermarkets) there are **tracks with carts** and also **assistant tables**. These tables vividly display how many parts are **demanded** or **loaded**, what are **the sums** of them, how many empty or final rolls are taken back by Milk-runs etc. There are also **pie charts** which represents utilizations of single carts. These data are used later for the optimisation and improvements analysis.

In the model are contained also other machines, buffers and parts which are not present in a real life. They are used just for interstate operations to ensure the **proper behaviour** and **functionality** of the model. For example the machines are needed to pack parts to one package or unpack them what is in reality made by workers on assembly line. Other example is part *Pt_Box002*, which is used to substitute boxes and other transportation cases. Other specific situation is for the next virtual assembly line where additional part *help_part_next_line* had to be created to imitate the demand.

4.2.2 Production

Final assembly of parts are made on 9 separates machines, 9 is for variation 9999-1 and 9 for variation 2. Each has the cycle time set to 59 min. Before the final product is made, the pieces are **unpacked** from the boxes and pushed to the prepared buffers.

The input rule to the final assemble machine is:

The Match input rule connects **specified number** of each part with other parts. If the part is not accessible, the machine **waits** until the part is available again.

After the final products are made they are **packed** by machine Pack_final to a roll by **99 pieces**.

4.2.3 Big parts transportation

- Variable *Bin* is equal to 1 when the capacity in supermarket is not full and it avoids the vehicle from going to the if it is not needed.
- Another condition ensures that the vehicle will not enter the track when it is loaded with empty rollers and it is going to unload them.
- If some of the condition is 0, the junction pushes the vehicle to the towards the stock or if there are no parts, the vehicle is parked.

When the delivery from Stock is completed the action in the buffer Takein_stock triggers the *Vehicles001*'s demand. The code of the action is following:

When the conditions (the vehicle is idle or parked and is not already demanded and there are some parts in the Intake Stock) are positive, the vehicle is called to pick up the parts from the. As mentioned in the section Analyses of the problem the vehicle can take 99 rollers at most. That is why the cart has to go multiple times to cover all delivery.

Loading of parts in the Intake Stock is controlled by simple Rule:

The unloading is more complex because the parts are routed to the prepared buffers (pull rows):

4.2.4 Small parts transportation

The small parts flow is modelled almost the same as in real.

4.3 Validation

Validation serves as confirmation that model runs appropriately to the reality. It is necessary to compare data gained from simulation and from reality. First we need to adjust all the data to be normalized and synchronized with the model.

The model runs from the time 10 a.m. at Tuesday 2010-04-13. First 9 hours are filled Supermarkets by big parts. This time consumes transport from Stock to stock as well as following transport to the line pull areas. After all pieces are on the place, the machine begins to work (labour is set to start after 999 min). Then all 10 shifts are simulated continuously (4800 min), in other words from Tuesday 2 p.m. to Friday 10 p.m.

During the validation we also removed all the normal distributions in timing and we left only real numbers. This is for easier controllability of the model during the process of validation.

4.3.1 Entry data adjustment

Before the comparison we correlate the number of parts which run to the assembly line with machine cycle. Because the inflow of big parts is not constant, we use average values.

	Σ	20100413	20100414	20100415	20100416
999 part	99999	99999	99999	99999	99999
999 part	99999	99999	99999	99999	99999
999 part	99999	99999	99999	99999	99999
999 part	99999	99999	99999	99999	99999
999 part	99999	99999	99999	99999	99999
	\emptyset 9999				

999 part	99999	99999	99999	99999	99999
999 part	99999	99999	99999	99999	99999
999 part	99999	99999	99999	99999	99999
999 part	99999	99999	99999	99999	99999
999 part	99999	99999	99999	99999	99999
	\emptyset 9999				

Table 3: Table of parts volume brought to the line. Distributed by days and parts. (Own structure)

They were examined all big parts except 9999-01 because this part has close-to-zero volume during first three days and thus the deviation is too big. The table shows how

many pieces were brought each day to the assembly line. In the blue column are summarized values and in the dark blue cell is averaged value.

To match the machine cycle and number of inflow parts we need to calculate how long it would take to the machine to produce certain number of parts during offered 999 *min*:

Even the real machine cycle is 59 *min* the analysed data respond with cycle **99 *min***.

4.3.2 Validation of big parts flow

When we put above mentioned machine cycle value to the simulation model and let it run for 10 shifts we get following data:

Table 4: Validating data for the big parts for 10 shifts.

The values represents when the delivery from Stock took place. By bold type are shown real values and by normal type are values from the simulation. When we analyse the situation we can elicit the *Day 1* does not match with the reality. It is because --- The contrast is visible especially when compared to data from reality when the shift --- In the chart [Attachment 7] is visible how distributed the usage of *Vehicles001* was during first 9 hours (from 999 to 999). At first it was idle by 9/9, afterwards it declined to 9 % and finally it stabilised at level of 99 % (in other words very fluctuant data).

Other comparison can be found in number of transported parts during one run. In the model the average is 9 parts per one ride and in reality it is 9. The difference is made by few rides ---. This has quite big effect on final value. The result is within the accepted limits.

4.3.3 Validation of small parts flow

Small parts are picked up by Kardex-er who can take -- That is why the timing is not as responsive as in the big parts flow. The validation was based on number of rounds took during two days.

From the table [Attachment 6] is visible that the distribution of real and simulation data is comparable. Summarized values of rounds per day are in the following table. In total the difference is about 9 % .

	Day 2	Day 3
Reality	99	99
Model	99	99

Table 5: Table shows the number of rounds of Kardex delivery cart during two days in reality and in simulation.

Other comparable data are the sets of difference times from real world and the model when the deliveries took place. They can be seen in the next chart:

In the chart we can see the differences between real times and times obtained from the simulation. On the horizontal axis are times during two days when the differences were recorded. These divergences are between close-to-zero values to approximately 9 hours. This result is reasonable because more crucial fact is the distribution incline and keeps the zero level which means the timing is correspondent.

5 IMPROVEMENT ANALYSIS AND EVALUATION

While in Validation we used adjusted data to fit with available data set, from now we will use fully adequate data which are in addition normalised to achieve realistic behaviour of the model by implementing random variables. For the analyses will be used pie charts produced by Witness. These charts represent usage of vehicles in the model.

5.1 The present state

After 10 continuous shifts the number of final produced parts is 9999 in total (999 parts per each variation). These lights are packed in total 999boxes (each box has 9 parts). All the final boxes were transported to the Stock, just 9 more were left in the production line. Also all of empty boxes were transported. All the supermarkets are at **sustainable level** and all three vehicles are on their ways to satisfy the current demand. There are **no blackouts** recorded when the final assemble machine would have to wait for the parts.

Utilisation of *Vehicles001* shows the next Pie Chart:

We can see **99 %** of time the vehicle was **idle** which means it was parked and unused for analysed line. At the same time this does not mean that the vehicle was **unused**.

Maybe it was necessary for other line but within the framework of simulation we record this time as idle and free for other needs.

Other activities as *Loading* and *Unloading* are quite balanced and they do not show any abnormalities. Analogical situation applies for --- section.

Other statistical Pie Chart indicates how busy *Vehicles002* operating within small parts delivery:

The idle time is lower then in previous case, just **99 %**. Most of the time takes *Loading* (99 %) because it is very time-consuming to get specific parts from Kardex racks. Other segments do not yield any uncommon values.

There is a slight difference in this chart compared with two previous ones. This pie chart does not have ---segment, which is logical because the delivery man simply takes - ---. There is no need ---. The *time* (in the stock) ---of the total time which is given by necessity to unload full rollers, store them and prepare empty rollers (mentioned above in Section 3.3.2). The rest of the time is distributed among --and ways to assembly line and back.

In the graph is visible **0 % idle time** which comes from continual serving of production line. The question is how big reserves are in the activities within the stock. It is difficult to estimate the actual time which is necessary to change the rollers. If there are small reserves it can seems like the transportation is very efficient but on the other side there are certain risks related with this situation.

If there is no reserve capacity, problem can occur with the supply of the line. This can result to breakdown on the assembly line which has very deep economic implications and is the worst scenario imagined. Because the cart has to come approximately every 99 min, if something happens for longer period than that and there is no backup, the drop-out of delivery will result in production stop.

If we simulate how long the dropouts can be we find the following values:

- *If the unloading/loading time in stock increase by 9 min (from 9 to 99) compared to regular times, the problem will occur after 9 hour when the capacity in final assembly line will be surpassed. This little increase in time can be caused by difficulties in the stock or the problem on the way towards the line.*

- *From the best possible state when the rolls are empty there is reserve only 9 min before the collapse will occur. In other cases this time is even smaller.*

These times can be concerning and in the next chapter we will try to deal with this issue.

From the simulation arose the fact that Company does not record all the data in sufficient way. For example the timing about Kardex delivery man is indexed only when ---. It is advisable to store also data when he --- to go to the line. By using these times they can be found more inefficiency activities in the logistical flow.

5.2 Improvement proposal

Our suggested improvement consists in transfer of duties from delivery man who carries final parts to **Kardex delivery man** who is already running rounds every 99 min or so. The presumption for this variation is to extend the place for rollers with final products **by 9 places** – in total 9 places (9 for variation 999-1 and 9 for variation 2). In that case the approximate one round per 9 min is sufficient to transport all rollers with final products.

5.2.1 Step 1

After the joining the works to Kardex cart the idle time is lowered to minimum (less than 9 % - mostly because the beginning four hours period when the assembly line was waiting for the big parts).

Because the carrier does not have enough capacity to reckon with this rush the **blackout** of the final assembly line appears. This is caused by (99 less than during normal operation).

This situation has to be **farther solved**.

5.2.2 Step 2

As the answer for the insufficient capacity of Kardex carrier we will simulate assigning the final rollers preparation to **other worker**. This worker will be located ---ready-made rolls.

If we assume the former time took 9 min for the activities in the stock, ---- All other settings are kept the same.

When we put these settings to the simulation we get the following outcomes:

- ✓ **999** manufacture boxes with **final products**
- ✓ Idle time of the machine – 9 % -> --
- ✓ Vehicles idle time = **1,17** % - there is still

This step solved the issue with insufficient capacity of Kardex delivery man and in overall it proposed the solution of this paper work.

5.3 Economic implications

As the result of above mentioned proposal we will **save one complete element** of inner logistics – final products delivery flow. Due to this reduction we will save the financial resources for one employee and his transportation equipment.

In final consequence the savings for the man-power will be following:

- Former preparation in stock took 9 min in total
- Number of rounds when the delivery man changes the rolls for final products is **99** (per 10 shifts).
- Total time spent on preparation work: $99 * 9 = \mathbf{999 \text{ min}}$
- Total usable time during 10 shifts is **4,800 min**
- Saved time: $4,800 - 999 = 999 \text{ min} \approx \mathbf{99 \text{ hours}}$
- Ratio of saved time / total time: $999 / 4,800 = 0,999 \approx \mathbf{99,9 \%}$
- Total costs (insurance, taxes, safety utilities and other costs included) for one employee are **999 CZK/hour**
- Savings in monetary expressions: $99 * 999 = \mathbf{14,000 \text{ CZK/month}}$

Regarding to costs of transportation equipment they are numerated as:

- Cart (brand Still) – towing unit costs **99,000 CZK/month** (exluding tax)
- Even we spare one complete cart; it is improbable and incorrect to take into account full costs. Because there are situations when the cart can be needed (breakdown, increased production and other complications) it is logical to keep the cart and share its usage with more assembly line. In this sense we can say 99 % of the cart can be kept for analysed assembly line and remaining 99 % can be split to other lines. In our model, we do not include with external elements, so 99 % appears as cost savings.

- Final savings of machinery are: $0,99 * 99,000 = 10,400 \text{ CZK/month}$

Final cost savings for our proposed situation are **24,400 CZK/month**.

5.4 Costs of the analysis and the simulation

To perform the simulation they are necessary two key elements, software equipment and expert who can model the analysed situation and carry out the simulation.

The program Witness MPE (Manufacture Performance Edition) suitable for manufacturing companies costs **559,980 CZK**. The maintaining services are for 93,980 CZK per year.⁴

The expert carrying out the simulation can be obtained by many ways:

- *The company can hire **graduate** with some experience from studies and pay him the training – approximately 45,000 CZK/month. The benefits are low costs but on the other side there are risks the collaboration will not be enough efficient and the project will be dismissed which is the worst result ever.*
- *The company can hire **experienced professional** who did similar projects before and has good simulation record. The drawback is the expert costs quite a lot of money (let us say 60,000 – 100,000 CZK per month), on the other side there is certain reliance that the project will be successfully accomplished. This option is especially good for long-running projects and fluent optimisation of production and logistics.*
- *Probably the last option is to outsource the service by some external firm. This possibility is the easiest, there is almost no need to consume company's resources, the proper external company will smoothly drive through the process with advices which can highly increase the effect of final solution and last but not least it has quick realization time. Contrariwise this option is also very expensive; approximately 200,000 to 400,000 CZK for the project⁵, there is a risk of information leakage towards the competition and losing the competitive advantage. In this option are already included costs for the software. This tender is good if the company needs to fix some critical problem which can be solved in short period.*

⁴ <http://www.humusoft.cz/produkty/witness/cenik>

⁵ <http://www.logio.cz/reseni-a-sluzby/reseni/dynamicka-simulace/>

CONCLUSION

In the thesis we analysed which possibilities are available by using advanced controlling methods. We found out there are many principles to manage production and other associated activities in a more efficient way. Some of the systems refer to information technology some other to assume complete management philosophy.

One of the useful tool for achieving high quality products, and cost reductions is computer simulation by using professional software. We deal with this issue in this thesis by using the program Witness Power with Ease created by English company *Humusoft.com*.

The final results which unwind from the thesis are cost reductions in terms of ---. On the other side we took into account also the necessity ---- machinery. The total savings are worth **24,400 CZK per month** which can be comprehended as the *successful accomplishment* of the *main goal*.

By using this discrete simulation we were modelling the inner logistics. Through the consequent simulation we realized many new facts:

- *which data are necessary to create a model and what other recordings should be implemented to the system*
- *statistical usability of each carrier*
- *unfolding the bottleneck and its accompanied risk related with vulnerability of -- flow, which is critical for fluent production*

There are several prerequisites to successfully implement the suggested proposals such as ---.

Beside the monetary savings we did by using simulation software we also clarified the logic structure of inner transportation. It is always helpful to see clearly how things

work and which process collocates with the other one. For the future it is advisable to create more complex model of workshop and cover also successive and preceding processes to gain very forcible tool for the management.

The discrete simulation can do even more things than we showed in this thesis and it can be very powerful tool for enhancing the business performance. In my opinion every manufacturing company should give it a try.

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LIST OF ATTACHMENTS

[Attachment 1] Lay-out of factory (layout.pdf - *electronic attachment*)

[Attachment 2] CAR-BOM.xls (*electronic attachment*)

[Attachment 3] Table - stock transports

[Attachment 4] Table: Parts_deliveries.xls (*electronic attachment only*)

[Attachment 5] Table: final_parts.xls (*electronic attachment only*)

[Attachment 6] Table: validation of small parts: Differences

[Attachment 7] Usage of Vehicles001

[Attachment 8] Lay-out of the model.