VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
FACULTY OF MECHANICS
DEPARTMENT OF INDUSTRIAL ENTERPRISE MANAGEMENT

Daiva, Urbonaitė

“KANBAN” SYSTEMS IMPLEMENTATION IN INDUSTRIAL ENTERPRISES
“KANBAN” SISTEMOS TAIKYMAS PRAMONĖS ĮMONĖSE

Final Master Work

Studies‘ program: Industry Engineering and Management, State Code 62608T204
Study area of Industrial Engineering

Vilnius, 2011

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Daiva, Urbonaitė

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Supervisor	(Science degree, name, surname)	(Signature)	(Date)
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Vilnius, 2011

VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS
MECHANIKOS FAKULTETAS
PRAMONĖS ĮMONIŲ VALDYMO KATEDRA

TVIRTINU
Katedros vedėjas

Pramonės inžinerijos studijų kryptis

Pramonės inžinerijos ir vadybos studijų programa, valstybinis kodas 62608T204

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BAIGIAMOJO MAGISTRO DARBO
UŽDUOTIS

.... Nr. ....

Vilnius

Studentui (ei) ....… Daivai Urbonaitei ……..............................…..…........…...
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BAIGIAMOJO DARBO UŽDUOTIS:

1. Atlikti literatūros ,,Kanban“ sistemos taikymo pramonės įmonėse temos teorinių aspektų analizę.
2. Atlikti pramonės įmonių klasifikacijos ir specifinių bruožų analizę.
3. Atlikti ,,Kanban“ sistemos taikymo pramonės įmonėse teorinių modelių analizę.
4. Atlikti ,,Kanban“ sistemos taikymo pramonės įmonėse empirinius tyrimus.
5. Atlikus teorinių ir empirinių aspektų analizę parengti ,,Kanban“ sistemos taikymo pramonės įmonėse modelį.

Baigiamojo darbo rengimo konsultantai:
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Title: **"Kanban" Systems Implementation in Industrial Enterprises**

Author **Daiva Urbonaitė** Academic supervisor **Assoc Prof Dr Rolandas Strazdas**

Thesis language

- [ ] Lithuanian
- [x] English

Annotation

In the final master's work Kanban systems implementation in industrial enterprises process, the particularity of this system, the implementation process, the problems which appear during this process are analyzed. The main purpose of this work is to prepare Kanban systems implementation model in industrial enterprises. This model will fit most industrial enterprises which specialize in manufacture of non-domestic cooling and ventilation equipment.

To achieve the objectives, first of all, various authors' methodical literature that is connected with contents of the thesis was analyzed and studied. Moreover, statistical surveys have been carried out to know current situation and its trends in the chosen industry. Also in this thesis the survey questionnaire was prepared for the enterprises in order to ascertain whether the enterprise is familiar with Kanban system and what are the main problems relate to the implementation of this system.

According to theoretical and empirical research results was created Kanban system implementation model for the industrial enterprises. After analyzing other authors' suggested models I missed the clarity and informative in it, I think that my model would help the companies which are starting to implement Kanban system.

After analyzing the aspects of theoretical and empirical research of the Kanban system implementation in industrial enterprises, the conclusions and proposals of the final work have been set.

Structure: introduction, 4 sections, conclusions, references.

Thesis consists of: 76 p. text without appendixes, 31 pictures, 15 tables, 45 bibliographical entries.

Appendixes included.

Keywords: Industry, Kanban system, implementation, enterprise, Kanban implementation model.

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Antrosios pakopos studijų **Prmaonės inžinerijos ir vadybos** programos baigiamasis darbas

Pavadinimas **“Kanban” Systems Implementation in Industrial Enterprises**

Autorius **Daiva Urbonaitė** Vadovas **Assoc Prof Dr Rolandas Strazdas**

Thesis language

☐ Lithuanian

☒ English

Anotacija

Baigiamajame magistro darbe nagrinėjamas ,,Kanban“ sistemos taikymas pramonės įmonėse, šios sistemos specifika, analizuojamas diegimo procesas, kylančios problemos, analizuojama šios sistemos reikšmė įmonėms. Pagrindinis darbo tikslas – atlikus tyrimus parengti ,,Kanban“ sistemos taikymo modelį pramonės įmonėms.

Darbo tikslus pasiekti pirmiausia buvo analizuojama ir studijuojama įvairių autorių metodinė literatūra, susijusi su darbo turiniu. Buvo atlikti statistiniai tyrimai kurių metu susipažįstama su pasirinktos pramonės šakos esamomis tendencijomis. Taip pat darbe atliekamas bendras metalo apdirbimo įmonių tyrimas, bei giluminis nebuitinių aušinimo ir vedinimo įrenginių gamybos įmonių tyrimas, kurių metu yra siekiamai išsiaiškinti ar įmonės yra susipažinusios su šia gamybos valdymo sistema, kokios pagrindinės problemos kyla diegiant šią sistemą.

Remiantis atliktai teoriniais ir praktiniais tyrimais, sudaromas naujas ,,Kanban“ sistemos taikymo modelis pramonės įmonėms.

Išnagrinėjus teorinius ir praktinius ,,Kanban“ sistemos taikymo pramonės įmonėse aspektus, pateikiamos baigiamojo darbo išvados ir pasiūlymai.

Darbą sudaro 7 dalys: badas, 4 skyriai, išvados ir pasiūlymai, literatūros sąrašas.

Darbo apimtis – 76p. teksto be priedų, 31 iliustr., 15 lent., 45 bibliografiniai šaltiniai. Atskirai pridedami darbo priedai.

Prasminiai žodžiai

Pramonė, Kanban sistema, taikymas, įmonė, Kanban diegimo modelis.

(the document of Declaration of Authorship in the Final Degree Project)

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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(Student‘s given name, family name, certificate number)

Mechanics
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Industrial Engineering and Management, PIVfmu-09
(Study programme, academic group no.)

**DECLARATION OF AUTHORSHIP
IN THE FINAL DEGREE PROJECT**

2011.05.23
(Date)

I declare that my Final Degree Project entitled __Kanban Systems Implementation in Industrial Enterprises________________________________ is entirely my own work. The title was confirmed on ____2009.11.05_____ by Faculty Dean's order
(Date)
No. ____________. I have clearly signalled the presence of quoted or paraphrased material and referenced all sources.

I have acknowledged appropriately any assistance I have received by the following professionals/advisers: ________________________________

The academic supervisor of my Final Degree Project is ___ Assoc Prof Dr Rolandas Strazdas ________________________ .

No contribution of any other person was obtained, nor did I buy my Final Degree Project.

DAIVA URBONAITĖ

(Signature) (Given name, family name)

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INTRODUCTION

Research actuality. In the industry all the time must continually be implemented new organization systems which would help to improve the production flow and reduce high production cost that would be possible to manufacture profitably. Enterprises are trying to find a way how to produce goods in the required amount at the required time, at the lowest cost and highest quality. To reach these goals, the industry needs to go through a change. Enterprises are starting to take interest and implement on of the Lean manufacturing tool called “Kanban” system in order to achieve the desired results. Kanban system methodology is established in Japan. After reading a description what is Kanban it can sound easy to understand and to use it, but it can be harder than you expect. To install successfully this system has to be done reliable model, which could enable greeter majority of industrial enterprises to perform better implementation process of it has to be done.

Novelty. Implementation of the Kanban system into industrial enterprises was not examined by Lithuanian scientists. Lithuanian industries do not know a lot about the Kanban system, just but few enterprises know what it is all about in reality. Enterprises in Lithuania are afraid of new changes within the company even if it can bring benefits in the organization of the production. Kanban system helps to increase productivity and flexibility in the enterprises.

Problem. Situation of industrial companies is always concerned with a high production costs and one of the factors that influence this is inefficient inventory management, what a result Kanban system is started to use. Most of the companies do know how to install successfully this system, because of this the main problem of this research is to find the best solution, how to improve Kanban system implementation into industrial enterprises that it could help to avoid the recurred mistakes.

Purpose. After analysis of the theoretical and practical material the model of the Kanban Systems Implementation in Industrial Enterprises was prepared. This has to include research of trends in Lithuanian industrial enterprises, analysis of the problems in X industry that appears by using Kanban system in Lithuania and analysis of the Kanban system implementation and use in one or several industrial enterprises.

Research objectives. Objectives of the final master thesis are:

1. To make analysis of scientific methodical literature of the topic – Kanban systems implementation in industrial enterprises.
2. To make analysis of industry classification and specific features of it.

3. To make analysis of theoretical models of Kanban system implementation into industrial enterprises.
4. To make empirical research in the industrial enterprises of the Kanban system.
5. After the analysis of the theoretical and empirical aspects to prepare a model of the Kanban system for the industrial enterprises.

Scientific value. Scientific value of this work is:

1. It is lack of information and research in Lithuania regarding Kanban system and its implementation process.
2. From the research, I observe that many authors are suggesting Kanban system implementation process in different ways, it is difficult to understand easy suggested models, that a result I propose alternative Kanban system implementation model.
3. Proposed model of Kanban system implementation process, according theoretical part and empirical research results gives some advantages of the system which are given below:
    - Enterprise can reduce lead times;
    - Enterprise can improve higher degree of supply capability;
    - Enterprise can increase transparency;
    - Enterprise can reduce material inventories;
    - Proposed model would help to optimize the flow of materials.

The research methods. The objective of research is proposing Kanban system implementation model regarding enterprises condition. This was accomplished by means of questionnaires, other research opinion theoretical background and collecting information on Kanban system implementation process.

Research strategy. Applying the research process and research approach, existing theory and the empirical material were used to dosing specific Kanban system implementation model for industrial enterprises.

Hypothesis. Increase efficient management of inventory has a big impact into decreasing high production costs and saving of their results in the time of global market.

1. RELEVANCE AND IMPORTANCE OF THE PROBLEM

Nowadays enterprises are trying to find solutions to difficult problems which start from scheduling to quality control or from budgets to communications in the companies. Production is one of the most changing segments of the business. Solutions to problems are therefore often unique.

Companies in Lithuania and in other countries around the word have various problems in manufacturing process. The main problems would be the following:

- *Accumulation of the reserve*. Without knowing the consumer demand it can be made unavoidable additional products or their components this affects the accumulation of products in stock, it is impossible to avoid using the traditional methods of organization. Traditional methods of organization encourage employees to load the equipments and manufacture as much as possible despite the real demand.
- *Storage necessity*. If the production overruns or excesses it has to be stored which requires additional space and cost for storage areas, accounting, transport and etc. It is necessary to pay not only for additional rental rates (if it is rented), but also for use of electricity and heating services.
- *Production defect*. There is a risk if the manufacture will be stored for a long time, production can be damaged or it will be necessary to remake, it will make additional costs and work time.
- *Inefficient materials management system*. Not knowing the exact quantity of materials needed for production may lead to excess or shortage of materials. The excess of materials has to be stored, it takes additional costs. The money which was spent on excess of material could be used for other company uses.
- *Poor work organization and delivery of information*. Bad providing detailed information between different divisions within the company (for example between manufacturing operators and logistical personal and etc.). Poor organization of the company does not encourage an efficient work in it.

Fig. 1 show the Problem Tree, where we can see main problems which influence high production costs. Moreover, Problem Tree presents sub-problems which occur under main problems in the production.

All these mentioned problems comes into one problem which is inefficient inventory management system in the industry and just this one problem can affect strongly the enterprises and it comes as a result high production costs.

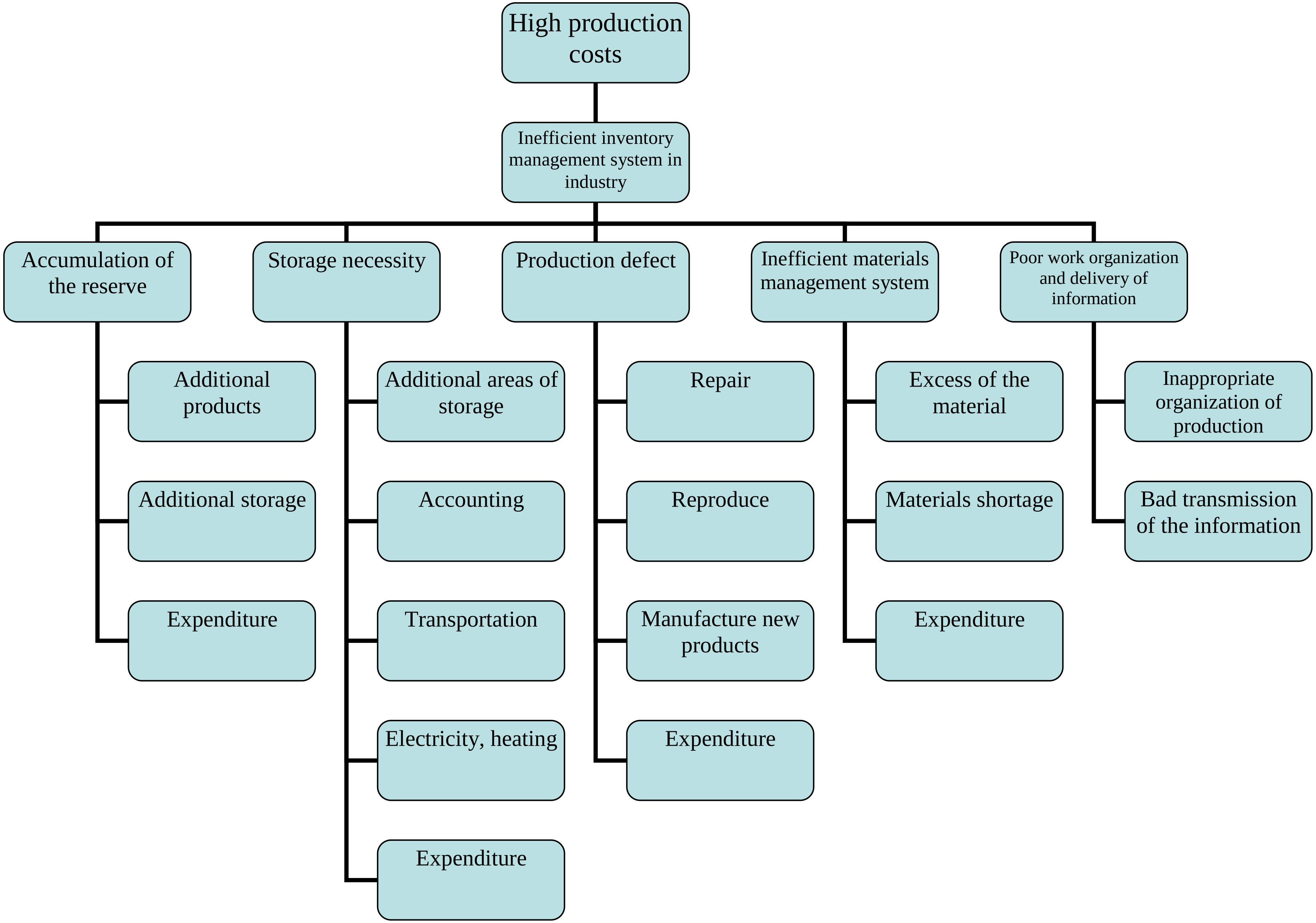
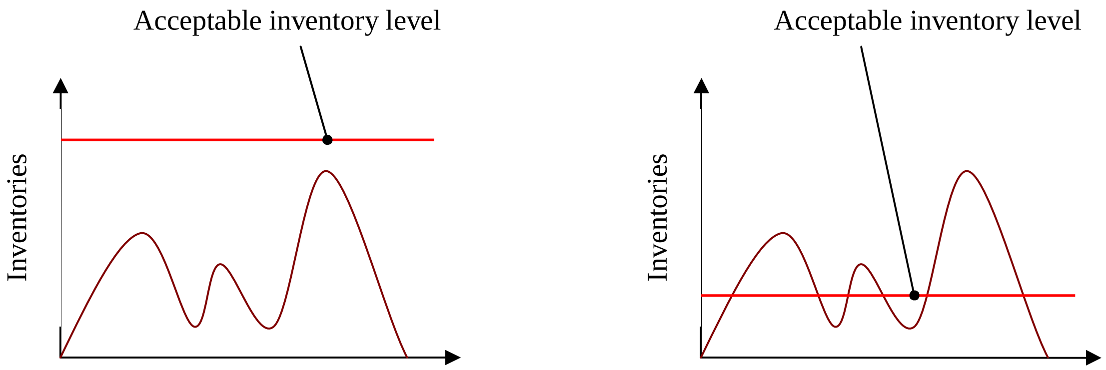


Fig. 1 Problem Tree

Listed problems are relevant to the various branches of industry sector, no matter what size of the company is or what kind of products are produced. The main key, for the enterprises, is to solve the problems.

Today it is topical because of these reasons:

- Intention to ensure a continuous production process ;
- Intention to avoid the various costs ;
- Electricity and heating prices are rising;
- Opportunity to invest or to save money;
- It is appropriate to use the services of suppliers which would timely deliver to the place of manufacture the necessary materials of other components which are necessary for the production.



a) b)

Fig. 2 a) Inventories facilitate; b) Inventories hide

The influence of material inventories what other problems that make inefficient inventory management system are in the industry. Fig. 2 shows that there can be two inventory's flows. When inventories facilitate it means that production is smooth, the delivery is immediate, manufacturing is cost-effective and capacity utilization is constant, but it happens not all the time, a lot of problems is hidden beyond bad management of inventory. Inventory's hide big scrap values, uncoordinated capacities, problems with delivery dates.

As a solution to the existing problems, in my final work, I chose the Kanban production control system, because it can:

- *Reduce inventory and product obsolescence.* Since component parts are not delivered until just before they are needed, there is a reduced need for storage space. Kanban can help to reduce inventory by nearly 50 %. [1]
- *Reduce waste and scrap.* Products and components are only manufactured when they are needed. This eliminates overproduction. Raw materials are not delivered until they are needed, reducing

waste and cutting storage costs. [15] By using a Kanban scheduling system where you specify thee production container sizes and the maximum number of containers to produce, overproduction can be greatly reduced. [1]

- *Provides flexibility in production.* If there is a sudden drop in demand for a product, Kanban ensures you are not stuck with excess inventory. This gives the flexibility to rapidly respond to a changing demand.
- *Increases output.* The flow of the Kanban (cards, bins, pallets, etc.) will stop if there is a production problem. This makes problems visible quickly, allowing them to be corrected. Kanban reduces wait times by making supplies more accessible and breaking down administrative barriers.
- *Reduce total cost.* By: preventing over production, developing flexible work stations, reducing waste and scrap, minimizing wait times and logistics costs, reducing stock levels and overhead costs, reducing inventory costs. [15]

In addition, the free space in your facility can then be used for new business opportunities, or it may even eliminate the need for expansion plans if that is in the works. [1]

2. THEORETICAL ASPECTS OF KANBAN SYSTEMS IMPLEMENTATION IN INDUSTRIAL ENTERPRISES

Analysis of the theoretical aspects consists of the basic concepts and classifications. This is done by analyzing the literature of other authors and their proposed solutions. A number of different sources of literature have been examined and the information in it has been assessed

2.1. Analysis of the industry definition and industry classifications

Industry can be understood in different ways, as an economic sector which is dominated by production and includes large amounts of capital. Industry can be seen as a grouping of business activities in accordance with certain features.

An **industry** is the manufacturing of a good or service within a category. Although industry is a broad term for any kind of economic production, in economics and urban planning industry is a synonym for the secondary sector, which is a type of economic activity involved in the manufacturing of raw materials into goods and products. [15]

There are many different kinds of industries, and often organized into different classes or sectors by a variety of industrial classifications.

In the research work I chose the detailed classification which is known in the Europe – NACE. NACE – Classification of Economic Activities in the European Community, and it is concerned with other very important standard in the industry named – ISIC, International Standard Industrial Classification of all Economic Activities. NACE is the “statistical classification of economic activities in the European Community” and is the subject of legislation at the European Union, which imposes the use of the classification uniformly within all the Member States. [24]

The comparability at world level of statistics produced on the basis of NACE is due to the fact that NACE is part of an integrated system of statistical classifications, developed mainly under the auspices of the United Nations Statistical Division. From the European point of view, this system can be represented as follows in fig. 3. [24]

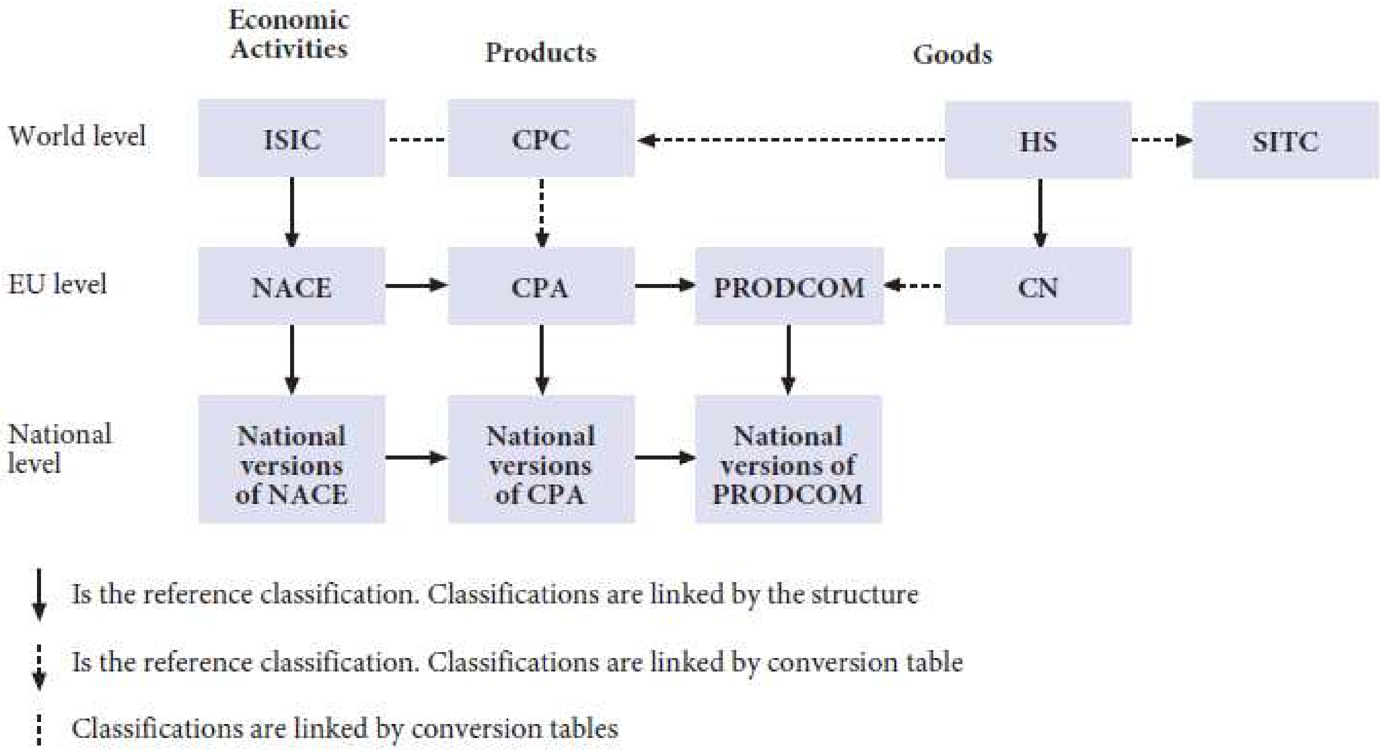


Fig. 3 The International systems of classifications [24]

Where:

- ISIC is the United Nations' International Standard Industrial Classification of all Economic Activities.
- CPC is the United Nations' Central Product Classification.
- HS is the Harmonized Commodity Description and Coding System, managed by the World Customs Organisation.
- CPA is the European Classification of Products by Activity.
- Prodcom8 is the classification of goods used for statistics on industrial production in the EU.
- CN stands for the Combined Nomenclature, a European classification of goods used for foreign trade statistics.

The structure of NACE is described in the NACE Regulation as follows: [24, p.15]

- A first level consisting of headings identified by an alphabetical code (sections);
- A second level consisting of headings identified by a two-digit numerical code (divisions);
- A third level consisting of headings identified by a three-digit numerical code (groups);
- A fourth level consisting of headings identified by a four-digit numerical code (classes);

Moreover, the enterprises can be classified in various criteria as all industry, by: type, organizational form of production and size of the company, see table 1.

Table 1 The enterprise classification of the various criteria

Criterion	Enterprise Groups
Production Types [23, p.11]	• Production unit – are made of individual products or small quantities of products and usually there are no plans to produce them again. • Mass production – continuously for a long time manufactured the same products, without changing their structure. • Serial production – where the products are produced recurring numbers and lots repetition expected in advance.
Organizational form of production [23, p. 12]	• Non-stream production – effective when produced in many different types of products in small quantities. • Stream production – a typical series of large quantity production.
Size [19]	• A large company – when the company employs 250 or more people; • Medium-sized enterprise – when the company employs fewer then 250 employees; • A small business – when the company employs fewer than 50 employees; • Micro-enterprise – when the company employs fewer than 10 employees.

There are many other classifications, for example: NAIVS sectors – North American Industry Classification System, which classifies industry in 20 types of industry; SIC – Standard Industrial Classification. But in my master thesis I'm interested how industry is classified by Lithuanian standards.

The industry includes sectors of the economy, service area, production and services. It consists of branches in economic terms; perform certain activities related to production.

Industry classifications compose various different groups of companies which operate in the same economy or share a similar type of business. Classification describes the business carried out by groups or their activities.

NACE is classifying all industry into 21 sections, 88 divisions, 272 groups, 615 classes. 21 sections are represented in appendix 1.

In my work I'm concentrated just at one section – manufacturing. This section has: 24 divisions, 95 groups, 230 classes. Industry which is selected in this research work is shown in Fig. 4.

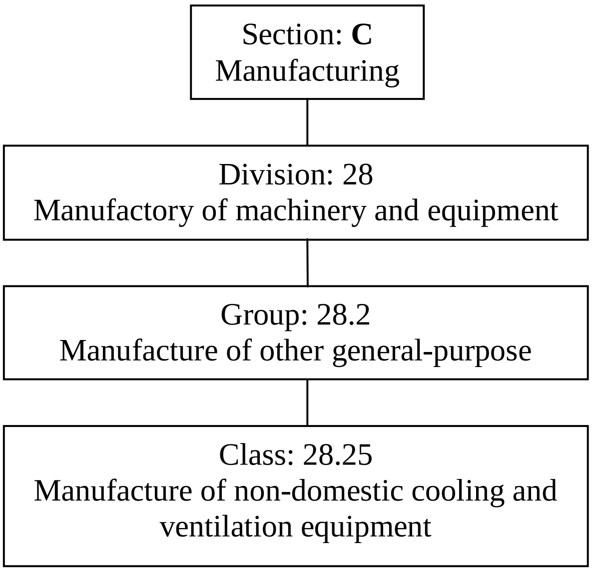


Fig. 4 Industry selection

Manufacture of non-domestic cooling and ventilation equipment class includes: [24, p. 180]

- Manufacture of refrigerating or freezing equipment, including assemblies of components;
- Manufacture of air-conditioning machines, including for motor vehicles;
- Manufacture of non-domestic fans;
- Manufacture of heat exchangers;
- Manufacture of machinery for liquefying air or gas;
- Manufacture of attic ventilation fans (gable fans, roof ventilators, etc.)

This class excludes:

- Manufacture of domestic refrigerating of freezing equipment;
- Manufacture of domestic fans.

Also, according to criterions for enterprises I chose enterprises according:

- Enterprise size;
- Production type.

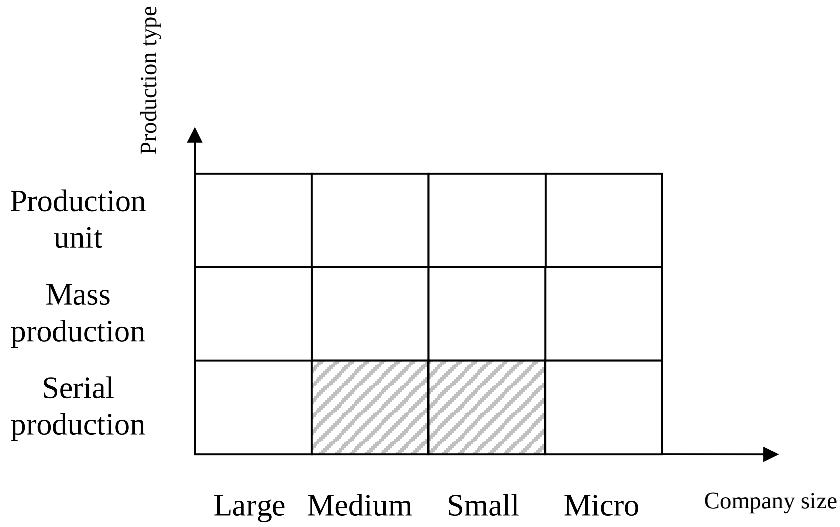


Fig. 5 Enterprises classification matrix

As it is seen in the enterprise classification matrix (fig. 5), the most improvement of Kanban system implementation model is suitable for medium and small size enterprises whose production type is serial production who has problems with inefficient inventory management system.

2.2.The specific lineaments and requirements for manufacture of non-domestic cooling and ventilation equipments

Each industry has the specific lineaments and requirement for the products which it is producing or services are providing. There is no exception for the enterprises from the industry which I chose, because it is very important that the products or services would satisfy the requirement of established standards in order to get the best results in the quality of the production and in the same time not to lose the confidence of the customers. The standard demand and quality management system have to be set in the enterprises.

Non-domestic cooling and ventilation systems are used in commercial buildings, schools, universities, dry labs, hospitals, stadiums, offices end etc. therefore ventilation system is also needed in and enclosed building to satisfy health, comfort and cooling needs.

Requirement for cooling and ventilation systems: [11]

- *External air quality*. The external quality environmental is an important factor to be considered when designing a ventilation system. Noise level, ambient air temperature and pollution from dust and smoke will determine if natural ventilation would be possible.
- *Occupancy levels*. Occupancy levels will determine the amount of air change that is required for a place depending on standard minimum requirements to satisfy health comfort and cooling needs of

occupants. According to the CIBSE Building Guide, the minimum required fresh air is 5 l/s per person while the recommended rate is 8 l/s per person.

- *Occupancy activity*. The type of activity people do in the place where the system is installed determines the required air changes and the ventilation system required. People moving around require more air than those are stationary.

Specific standards for this sector are:

- ISO 91.140.30 Ventilation and air-conditioning systems (ISO – International Organization for Standardization).
- EN779:2002 Standard for general ventilation filters, which was set by European Committee for Standardization.
- ISO 16813:2006 Building environment design; indoor environment; General principles.
- ISO 900 Standards related to quality management systems.
- and others specific standards.

Enterprises chose which standards they will be using. The key standards has been mentioned, other standards for production operations has to be set too, but in this part of the work I was concentrated in the standards which are set for the industry and not for the each operation.

2.3.Kanban System concept

Knowing what to make and when to make it is the central manufacturing problem. Most of the companies are using general "push" system where demand of the products or parts are predictable in the enterprises; it is based on the consumer's forecasts, this brings big problems for organizing your inventory, in order to have efficient inventory management system.

Ohno's insight was that "when you have lots of inventory you are always one part short". He was saying *"The more inventory a company has, … the less likely will have what they need"* – Taiichi Ohno. He decided that the problem could only be solved if each processing step went frequently to the previous processing step and picked up exactly the number of parts needed for the next increment of production. By adding the ironclad rule that the previous step would never produce more parts than the next step had just withdrawn. The *kanban* cards were introduced in 1953 to formalize the system and make information flow smoothly back-wards at the same rate products flowed forward [13, p. 206].

At Toyota every step of every manufacturing process has the equivalent of a built in, called *kanban*, to signal to the previous step when its parts need to be replenishment. This creates "pull" which continues cascading backwards to the beginning of the manufacturing cycle [14, p. 23].

In Aisin Seiki's Anjo plant in Japan, which produces mattresses, *kanban* model is used, and this system ensures that the minimum required number of the popular products is always in stock. This system allows flexibility to meet customer needs, with a use of kanban, popular products are replenished as soon as they are sold, thus minimizing inventory [21, p. 147]. As an example until Aisin implemented *kanban*, it had produced different types of mattresses on a weekly schedule, but under the new system, what had once been a weekly cycle of production was reduced to a daily cycle. Today, the cycle has been further reduced to two hours [21, p. 154].

According to Taiichi Ohno, *kanban* means sign, signboard, doorplate, poster, billboard, card but is taken more broadly as a signal of some kind. Send back an empty bin – a *kanban* – and it is a signal of refill it with a specific number of parts or send back a card with detailed information regarding the part and its location [14, p. 106-107].

The kanban principle is that the authority to produce or move a part is based on the usage of the part rather than on the calculated work to list [25, p. 113].

According to Markey M. (2005) a Kanban, the Japanese word for card, is a tool for implementing Just-in-Time (JIT) production. In its most common form, Kanban is simply a card that contains production information. This card identifies the part number, delivery and work cell locations, part descriptions, quantity, the name of the company and the card number within a series. This introduction about the Kanban system is similar to other authors' introductions who write about it. On order to understand this system it has to be written in simple and easy understandable words. Moreover, the main problems which Kanban can solve, such as: administration, space, inventory accuracy, degeneration of material, hidden quality problems. According to all these problems, competitive market dictates that companies are interested in survival so they become lean, agile and flexible. Also, Mertins K. and Lewandrowski U. (1999) write that control systems of efficient production should be flexible and lean. Pull control systems, especially Kanban systems, lead to optimized organizational structures and order processes.

Kanban system is associated with just-in-time production. Kanban is a production process management and an inventory control system. For the control a card or labels are used (and other measures can be used), which accompany the product throughout the production process by providing all necessary information about it. It also informs the appropriate amount of components without interruption to production. it involves more then just manufacturing. Other functions such as purchasing, warehousing, shipping and receiving, quality control, transportation, accounts payable and engineering are involved.

2.4. Classifications of Kanban system

Classification of the Kanban system is necessary to know which type of the Kanbans to use in the plant, because according to the existing situation in the area and the purpose of the Kanban system it is classified in some types of this system.

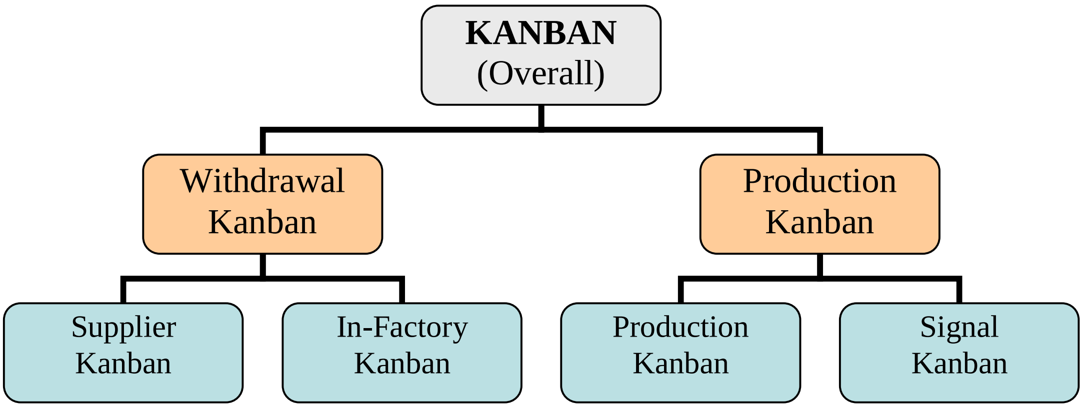


Fig. 6 Types of Kanban

The classification of the Kanban is illustrated in Fig 6. There are two main types of the Kanban system: are production Kanban and Withdrawal (transportation) Kanban. These two types are classified in more detailed classification by sub-types. Withdrawal Kanban (or transportation) Kanban is sub-typed as: supplier Kanban and in-factory Kanban; and production Kanban is sub-typed as: production Kanban (the same name) and signal Kanban.

- *A production (ordering) Kanban* is a printed card indicating the number of parts that need to be processed to replenish what customers have pulled. Moreover, it indicates operation instructions at specific processes (in-process Kanban; production cards). They are routinely used at processes that do not require changeovers. It initiates production to replace the parts that have been removed. [4]

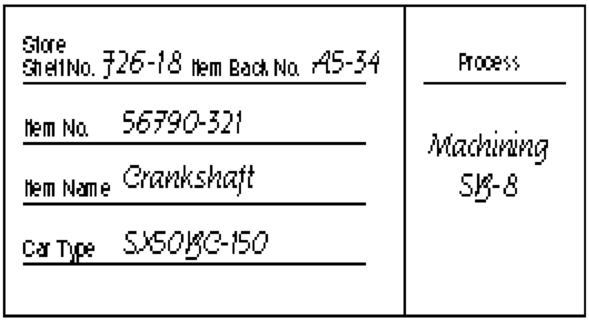


Fig. 7 A production – ordering Kanban [34]

The one illustrated (Fig. 7) shows that the machining process SB-8 must produce the crankshaft for the car type SX50BC-150. The crankshaft produced should be placed at store F26-18. The production-ordering Kanban is often called an in-process Kanban or simply a production Kanban.

- *A withdrawal Kanban* is a printed card indicating the number of parts to be removed from a supermarket and supplied downstream. [31] It indicates when numerous parts are to be moved to the production line, or between processes in production and assembly. [4]

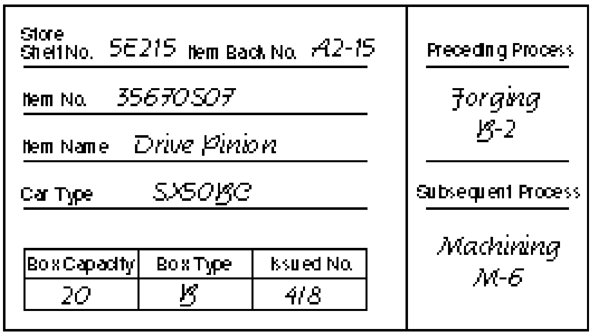
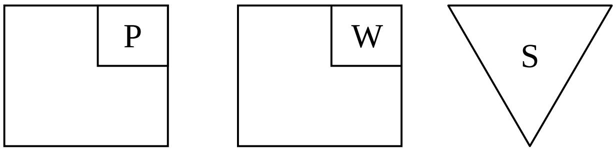


Fig. 8 A withdrawal Kanban [34]

The withdrawal Kanban illustrated (Fig. 8) shows that the preceding process which makes this part is forging, and the person carrying this Kanban from the subsequent process must go to position B-2 of the forging department to withdraw drive pinions. Each box of drive pinions contains 20 units and the shape of the box is `B'. This Kanban is the 4th of 8 issued. The item back number is an abbreviation of the item. [31]

- *A signal Kanban* is a printed card indicating the number of parts that need to be produced at a batch operation to replenish what has been pulled from the supermarket downstream. [29, p. 64] It is used in a large lot in process inventory (lot production Kanban). Signal Kanbans are used at presses or other processes requiring changeovers to signal when a changeover is needed in the sequence of production Kanbans. Triangle Kanbans are a special form of signal Kanban that call attention to the reorder point. [4]
- *Supplier Kanban* is the orders given to outside suppliers for parts needed at assembly lines. If the Kanban system has extended to the supplier network, then suppliers will deliver on demand as supplier Kanbans are received from the factory. [25]
- *In-Factory Kanban* authorizes an inside parts that has to be delivered from the storage to the areas where it is needed, used to indicate when parts are to be moved to production. Assembly lines also use parts and subassemblies that are produces within the factory. These are the Kanbans used between processed in the factory; they provide the details needed to withdrawal parts from an upstream process. [4]



a) b) c)

Fig. 9 a) Production Kanban b) Withdrawal Kanban c) Signal Kanban

Symbols how looks main Kanban types in different production analysing maps (for example:values stream map) see fig. 5.

John Bicheno is classifying Kanban in more detailed classification, which explains how these cards works, and when to choose which card according to the existing plant. [2, p.107]

- *Single Card Kanban* **-** Traditional kanban is suitable in all stable manufacturing environments where there is repetitive production. Single card kanban means that a single card (or pull signal) operates between each pair of workstations. Although there may be several single-card *kanbans* in a loop between a pair of workstations, each kanban is the authorization to both make a part or container of parts and to move it to a specified location.
- *Product Kanban* **-** With this type, whenever a product is used it is simply replaced. If there is no call, there is no authorization so there is no production. In practice, the variations of this type include kanban square (a vacant square is the authorization to fill the square with another similar part), cards (which are returned to the feeding workstation to authorize it to make a replacement quantity as specified on the card), and other variations such as “faxban” or “e-ban” (which operate in exactly the same way as cards, except that the pull signals are electronic not physical). [32, p. 108]
- *Generic Kanban* **-** Generic (or “capacity”) Kanban authorizes feeding work centres to make a part, but not specifies what part is to be made. The part to be made is specified via a manifest or a “broadcast” system. It is therefore the preferable pull system where there are a large number of products, all of which have similar routings and fairly similar time requirements at each workstation.
- *Signal Kanban* **-** Where there is a changeover, a signal (or triangle or priority) kanban is used. As parts are withdrawn, so Kanbans are hung on the board under the appropriate product column. A target batch size is calculated for each product and the target is marked on the board. When a sufficient number of Kanbans has accumulated to reach the target, a batch is made. This gives a visible up-to-date warning of an impending changeover.
- *Dual Card Kanban* **-** Uses both production and move kanban cards. Production (or signal) Kanbans stay at a particular work centre and alternative from Kanban board to finished goods

container. The work centre operator uses them. Conveyance Kanbans stay between a particular pair of workstations and alternate between move card mailbox and full container (with conveyance card attached). The material handler uses them. [32, p. 109]

- *Move Kanbans* **-** In the single card system, these are simply Kanbans that trigger parts delivery to the line, either from an internal supermarket or from an external supplier. In the dual card system, move Kanbans work with production Kanbans or signal Kanbans. [32, p. 109]

2.5. Basic operation of a Kanban control

Without understandable and strict control any system will not work properly. To understand how it works and how it has to be controlled a basic Kanban cycle will be explained step by step. The methodology of Kanban control systems is explained in more detail by the following description of a dual-card system, which is usually used in the enterprises. The due-card system is normally used where there are large distance between consumers and producers of products or where there is an independent transport system.

The scheme of the control, see appendix 2.

1. The starting point of a Kanban control loop is always the utilising production section. From there, an operator uses a transport Kanban to signal a requirement to the store of the preceding production process or to the organization responsible for transport.
2. In the storage the production Kanban is now removed from a full container holding the required parts. The production Kanban that has been removed is put in the Kanban collection box of the preceding production process.
3. The empty container is sent to the preceding production process.
4. Regularly the preceding production process according to the Production Kanban Cards in the Kanban collection box (hereby acknowledging constrains such as lot size etc.)
5. The number of parts produced is controlled by the # of Production Kanbans available for the preceding process. The parts are put into the related empty container(s).
6. The refilled containers are transported to the storage. The production cycle of Kanban-controlled part is completed by returning the Kanban lot to the store.

This is an example how Kanban system is working by using one of the Kanban classification type.

2.6. Calculations Kanban Size

After analyzing theoretical aspects of the Kanban system we can find different formulas how Kanban Size has to be calculated. This is surprising how something so simple can have so many variations. These calculations includes: Number of Kanban Size and Number of Kanbans.

Basic Kanban size calculations based on demand variation factor.

Kanban Size = Daily Demand · Replenishment Time · Mean Average Deviation to the daily rate

where: *Daily Demand* - Last years customers shipments / number of production days; Next "X" week forecast / production days; *Replenishment Time* - Total time from the signal until product is back in the Kanban; *Mean Average Deviation to the daily rate* - Any district order patterns?

Daily demand for Kanban has to be evaluated by real factors, it can't be guessed figures. Most companies has historical data regarding demand for each of their components or are able to calculate it from sales figures of component items. We try to take a figure that covers 90 % - 95 % of all daily demand.

The number of authorized Cards / Containers in a JIT system controls the amount of inventory in the system at any given time. It directly impacts the WIP inventory and safety stock. Material spends some time in actual processing, waiting in queue, waiting in a storage location or in transit. [16]

The Key to determining the number of Cards / Containers is estimating the average Lead Time needed to produce a container of parts.

$$\#\ of\ Cards = \frac{Average\ Demand \cdot Lead\ Time + Safety\ Stock}{Size\ of\ the\ Container\ (Kanban\ Size)}$$

where: *Lead Time* is a function of the processing time per container at the upstream station and the waiting time at the down stream production process and for material handling.

The safety factor in the calculation is to give a starting point from which to make improvements, you start with a "comfortable" safety factor then reduce it in planned steps and trackle problems, either these that you can predict that will arise and those that occur. The excessive amounts of inventory within a traditional manufacturing system tend to hide many problems; the lowering of this inventory will begin to uncover these problems. [7]

These selected formulas are the most widely used and in reality is very simple to calculate.

2.7. Analysis of the Kanban system implementation process

To implement the Kanban system is not so easy, because, as it is mentioned in John Gross article "Implementing successful Kanbans", many companies are afraid to use a "pull" control system. These companies fear to change; they fear to lose control; they fear to be run out of material; they fear to miss shipments; etc. these fears are a roadblock to implementation. It has to be a strong leadership for overcoming these fears. Moreover, developed plans have to be done for the implementation of Kanbans.

The success of the Kanban system depends largely on the company's preparedness to work with it. Some parts of Kanban may be suitable for one company, others may not. Not all parts of Kanban may be appropriate for the types of products you produce. Kanban may be appropriate for one product, but not for another. In some cases a simple manual Kanban will work well. In other cases computer automation of Kanbans may be the best option

To start the implementing Kanban, some elements for successful implementation have to be considered. Different authors suggest different elements for it. Analysis of the submitted solutions proposed by other authors is made, the analysis, what kind of the model they suggest for the Kanban System Implementation.

Preparation for a Kanban scheduling system can be formal with elaborate analyses and simulations. It can also be very informal with fine–tuning done on the production floor. Process Mapping can help to understand the underlying process and Value Stream Mapping uses Kanban in many places.

It has to be made Kanban System implementation model. Firstly, I represent other authors proposed models.

Suggested models:

1. Consultancy firm "Strategos International" suggests the following steps: [40]
   - Analyze Product-Volume For Upstream Work Center
   - Analyze Downstream Order Patterns
   - Indentify Kanban Products
   - Indentify Appropriate Lot Size
   - Indentify Containers
   - Indentify Signal Mechanism
   - Specify Stockpoint(s)
   - Specify Initial Kanban Quantities
   - Develop Upstream Scheduling Algorithm
   - Operate Fine tune

2. Taiichi Ohno states that in order to be effective Kanban must follow strict rules of usage and that close monitoring of these rules is a never-ending problem to ensure that Kanban does what it s required. [17]

   These rules are:
   - Do not send defective products to the subsequent process

- The subsequent process comes to withdraw only what is needed
- Produce only the exact quantity withdrawn by the subsequent process
- Equalize production
- Kanban is a means to fine tuning
- Stabilize and rationalize the process

3. Steve Hudgik in his article suggests to introduce Kanban in a such way: [41]

- The first step is to become familiar with Kanban and the options it offers.
- Select the components of Kanban that will work in your facility.
- Plan your Kanban system.
- Set goals for Kanban.
- Begin implementation of Kanban.

4. Mukhopadhyay S.K. and Shanker S. in their article divide Kanban implementation into three broad phases and classify each activity in each phase. Table 5 shows the overall steps of Kanban implementation in a model area. [43]

Table 2. Overall methodology

Phase	Particulars
Induction phase	Model area selection, training, design of Kanban card and board;
Implementation phase	5S, SMED, multi-skilling, SPC, Operating rules and other supporting activities.
Evaluation phase	Pilot run, evaluation against set values of parameters

Described details of implementation:

- Selection of model area
- Project team formulation
- Introductory education and campaign
- Kick-off
- Introduction of 5S in model area
- Layout improvement and identification system
- Multi-functional workmen training
- Reduction of setup time by SMED
- Implementation of SPC and visual control
- Pilot run, evaluation and full implementation of system

5. Gross, John in his article consider following elements for successful implementation:

- Size the Kanban’s to current operational conditionals.
- Adapt container sizes to allow better kanban control.
- Make kanban signals visual.
- Develop rules that provide decision points plus checks and balances.
- Train operators to run the kanban operators.
- Set up audit plans to keep assumptions current and maintain system discipline.
- Develop a phased improvement plan to reduce kanban quantities.

6. Resource Systems Group management consultancy suggests a simple kanban implementation plan: [42]

- Customer requirements: ABC analysis, demand segmentation & linearity
- People: involvement, training
- Process: observation, mapping, layout, changeover, run size, OEE, process linearity
- Kanban: one card, two cards.
- Materials handling, buffer stock location, organization
- Container: sizing, selection or design
- Visual design: card or container labels
- Kanban math
- Control system: recalculate # of cards, missing cards
- Design documentation

Table 3 is for the particular industry sector, it would be - Non-domestic cooling and ventilation equipment production and make the analysis of all the suggested models. Table 1 shows advantages (+) and disadvantages (-) of the solutions which are proposed by other authors.

Having considered all these mention models (table 3) for the implementing Kanban system from different authors I think that the best classification would be Mukhopadhyay S.K. and Shanker S’ classification, because after overall methodology they divided into big phases and smaller particulars, so it is more clear how everything has to be, and what small steps has to be done to reach the best results.

After all the analysis of models a common approach to implementing Kanban is to start with a generous number of Kanbans – containers, pallets, boxes, etc. Then systematically reduce the number of containers until the point at which the supply of materials is just in balance with the rate of use is reached. As containers are removed from the process, it will eventually reach the point at which production is delayed because the next container has not arrived yet. At this point add one container to the system to bring it back into balance.

Table 3. Kanban Implementation suggested models

Kanban Implementation models	+	-
1. Consultancy firm "Strategos International" model	+ informal with fine-tuning done on the production floor; + this mapping can use Kanban in many places (not just in one sector of industry); + The following steps are written particularly.	- Quite elaborate analysis has to be done. - An elaborate simulation has to be done. - It is not clear how all the steps have to be done.
2. Taiichi Ohno model	+ must follow strict rules;	-there are more rules, not explanations what has to be done.
3. Steve Hudgik model		- not enough information for the start of implementing the system
4. Mukhopadhyay S.K. and Shanker S model	+ it is classified in phases and particulars which has to be done; + all needed steps are informative; + it is clear what has to be done from the beginning till the end; + explains the evaluation of the system. + the best explained disc about induction phase	- needs a lot of time to accomplish all things; - near it a big project team has to work. - needs knowledge about some other systems;
5. Gross, John's model	+ simple explanation what has to be done; + understandable what has to be done	
6. Resources Systems Group management consultancy model	+ stated many steps which has to be done	- not all of the steps are clear what has to be done

When implementing Kanbans, the first step is to educate everyone involved in the use of Kanbans. Because Kanbans are different from the way most people are used to working, everyone using Kanbans must understand the rules otherwise they are very likely to undermine the Kanbans.

When the Kanban system is already implemented the factors that affect Kanban performance at the organizational level have to be examined. The Manufacturing Engineering Department of a small midwestern company implemented a Kanban system aimed at purchasing 95 % of their orders on time. Unfortunately, they were unable to achieve this goal (Adams, Stephanie G.). Analyzing this article I found that ineffective communication, weak reward system, incompatibility of expectations and a dissonance between values declared and values supported by the organizational systems create a culture focused on individualism and production rather than teamwork and quality. These factors are important to know for the implementation of new processes (Kanban System).

Recently these who already implemented Kanban system try to improve it. Hung-da Wan, F. Frank Chen in their article suggest to make a web-based Kanban system because the conventional Kanban systems using physical cards suffer from human errors, limited tracking capability and so on. But this is already about the how to improve Kanban System with a help of Web-base.

3. EMPIRICAL RESEARCH OF KANBAN SYSTEMS IMPLEMENTATION IN INDUSTRIAL ENTERPRISES

3.1.Empirical research structure

Empirical research methodology and process

This study is a part of what research methods were used and the investigation steps have been done.

Phases of the study:

I. Preparation for the research. This phase is released to:

1. To set the purpose and objectives

Purpose of the empirical research is to examine in more details and to justify the proposed solutions to the existing problem, which is related with a Kanban Systems implementation.

Selected industrial sector, according to the industry classification which was made in first research work is – non-domestic cooling and ventilation equipment production (according to classification of economical activities).

Goals of the empirical research:

a) To make analysis of Lithuanian X industry sector tendencies (it was made in the second research work).
b) To find out the main problems with which most companies are facing.
c) To investigate the use of Kanban system in enterprises.
d) To identify the key barriers which have been encountered in installing the system.
e) To identify the changes after implementing Kanban.

2. The process organization – selection of the methods.

Purpose is to make analysis of the selected sector.

Methods used in the study:

1. Collection of statistical data – to collect data on selected industry by using data sources/statistics from Lithuanian Development Agency and Lithuanian Department of Statistics, of evaluating the expression of which is chosen by industry to subject to any other in the sector.
2. Survey – a questionnaire for the enterprises.
3. Observation – to investigate implementation process in the company.
4. Correlation and regression analysis.

II. Collection of facts (empirical data collection).

Purpose. With a help of written questionnaire which is prepared on the basic of analyzed theory on Kanban System, to find out necessary information.

The methods used:

1. Determining the scale of the investigation – Calculation of sample size
2. Telephone and e-mail interview– overall performance of the survey to find companies which have implemented the system.
3. Deep interview – survey for the companies that implemented the system (2 main companies).
4. Confidence interval calculation.

III. Empirical data processing.

Purpose. Make an analysis of collected empirical data (the analysis of the questionnaire results).

3. Questionnaire results analysis (percentage evaluation, charts).
4. Questionnaire results analysis using SPSS computer program for statistical analysis.

3.2.Analysis of the industry

Analysis of the industry is made to carry out what is the current staged of the chosen industry.

According to classification by economic activities I chose industry sector which is called "Other machinery and equipment". This sector is divided into smaller sub sectors of the classification. Then I chose "Non-domestic cooling and ventilation equipment production". Moreover, this sector has small classifications too, from these classifications I chose the most important and interesting smaller sector such as: The air-conditioning equipment manufacturing and Industrial ventilators production. [3]

3.2.1. Percentage distribution of the enterprises

This percentage distribution evaluates what percentage part of the selected sector has comparing with other ones. The resource which I used to evaluate this percentage distribution is Lithuanian Development Agency, which is a public sector organization and where the total number of registered companies in database are 6 277 (this figure includes enterprises which are not related with any manufacturing industry).

According to the information from database of Lithuanian Development Agency I found out that manufacture enterprises is divided in big groups according to a fields of activity. Sector which I choose belongs to the – Manufacture of other general purpose machinery sub-group, which belongs to the main group - Manufacture of machinery and equipment n.c.s. This sub-group consists of **38** registered enterprises in database. It represents **2.42 %** of the manufacturing enterprises which are recorded there.

Table 4 Percentage distribution

Fields of activity	Distribution %
Manufacture of textiles	3.88
Manufacture of wearing apparel; dressing and dyeing of fur	2.36
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	**16.80**
Manufacture of pulp, paper and paper products	2.34
Publishing, printing and reproduction of recorded media	**10.57**
Manufacture of chemicals and chemical products	1.78
Manufacture of rubber and plastic products	**12.54**
Manufacture of other non-metallic mineral products	5.35
Manufacture of basic metals	1.59
Manufacture of fabricated metal products, except machinery and equipment	**11.52**
Manufacture of office machinery and computers	1.27
Manufacture of machinery and equipment n.c.s.	4.71
Manufacture of electrical machinery and apparatus n.e.c.	2.55
Manufacture of radio, television and communication equipment and apparatus	3.63
Manufacture of medical, precision and optical instruments, watches and clocks	0.64
Manufacture of food products and beverages	1.27
Manufacture of motor vehicles, trailers and semi-trailers	4.33
Manufacture of other transport equipment	3.25
Manufacture of furniture; manufacturing n.e.c.	0.70
Recycling	2.23
Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, hardness and footwear	**8.02**

As we can see from the table 4, we can see industry sectors share. The first five places takes:

1. 16.80 % - Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials.
2. 12.45 % - Manufacture of rubber and plastic products.
3. 11.52 % - Manufacture of fabricated metal products, except machinery and equipment.
4. 8.02 % - Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, hardness and footwear.

3.2.2. Analysis of the selected industry

The non-domestic cooling and ventilation equipment productions class includes: Industrial refrigeration or freezing equipment manufacturing; the air-conditioning equipment manufacturing; manufacture of heat exchangers; non-domestic cooling and ventilation equipment production. This class excludes: manufacture of agricultural dryers; household refrigerating or freezing equipment manufacturing; domestic ventilation equipment production.

The data is taken by Lithuanian Department of Statistics. This statistics indexes are about the main industry sector of these classifications –"Other machinery and equipment". I took this general information about this industry in this research work to understand what the main situation is in this sector.

Table 5. Market Industrial production, the marketing trends and indices, statistical indices in the year

Other machinery and equipment	**2006**	**2007**	**2008**	**2009**
Industrial production index, compared with 2005, %	127,7	142,3	220,9	160,0
Industrial production index, compared with the previous year, %	127,7	111,4	155,3	72,4
Sales and service on the Lithuanian market, %	49,4	47,2	31,6	27,0
Sales and services at the Lithuanian market, %	50,6	52,8	68,4	73,0
Industrial production at constant prices, thousand, LT	506 382	563 962	875 761	634 115
Industrial production (at current price, excluding VAT and excise duties), thous. LT	522 447	605 956	1 019 690	655 166

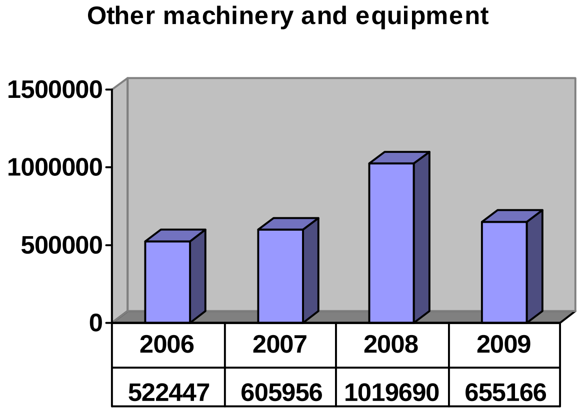


Fig. 10 Industrial production, thous. LT (Lithuanian Department of Statistics, 2009) [17]

According to 2006 - 2009 time of period, from table 5, we can see that this industry sector was growing till the 2008 by comparing numbers of the incomes of industrial output, fig. 10 shows visual view of it.

Table 6 Industrial production and indices, statistical indices in a quarter

Other machinery and equipment - 2009	**1st Qtr**	**2nd Qtr**	**3rd Qtr**	**4th Qtr**
Index, compared with 2005, %	160,4	154,6	154,9	170,0
Index, compared with the previous corresponding period, %	72,1	63,8	72,2	83,2
Index compared to previous period, %	78,5	96,4	100,2	109,7
Industrial production at constant 2005 prices of thousands, LT	158 932	153 201	153 531	168 451
Industrial production (excluding VAT and excise duty), at current prices, thousand, LT	179 836	160 288	149 252	165 790

Table 6 shows the statistical data of all the quarters of 2009 and one quarter of 2010. This data is compared with a data of 2005. According these indexes we can see that the best situation was on 2009K4. Moreover, the incomes, comparing 2005 and 2009 years are bigger in 2009 by 3.32 %.

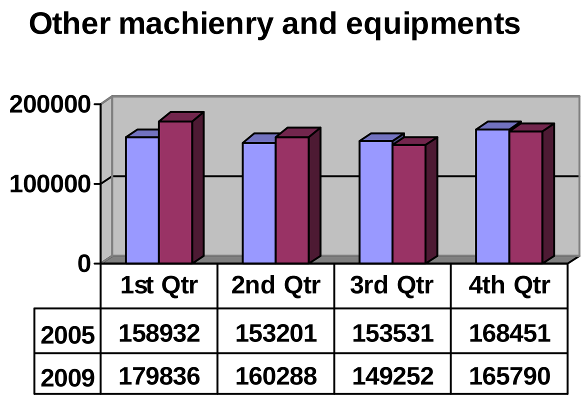


Fig. 11 Comparison on 2005 and 2009 incomes

Fig. 11 shows that there are not big differences between each year incomes of the quarters. During 2009 1st Qtr was the biggest incomes by comparing these two years.

Table 7 Industrial production and indices, statistical indices in a month

Other machinery and equipment - 2010	**Jan.**	**Feb.**	**Mar.**	**Apr.**
Index, compared with 2005, %	153,4	150,4	165,3	181,9
Index, compared with the previous corresponding period, %	95,6	94,7	98,3	120,0
Index compared to previous period, %	90,2	104,2	109,9	110,0
Industrial production at constant 2005 prices of thousands, LT	151 993	49 703	54 608	60 096
Industrial production (excluding VAT and excise duty), at current prices, thousand. LT	151 867	49 510	55 147	61 200

Table 6 is for the quarters of quarters in 2010, fig. 12 shows the visual view of it. Comparing the beginning from January till April of 2010.

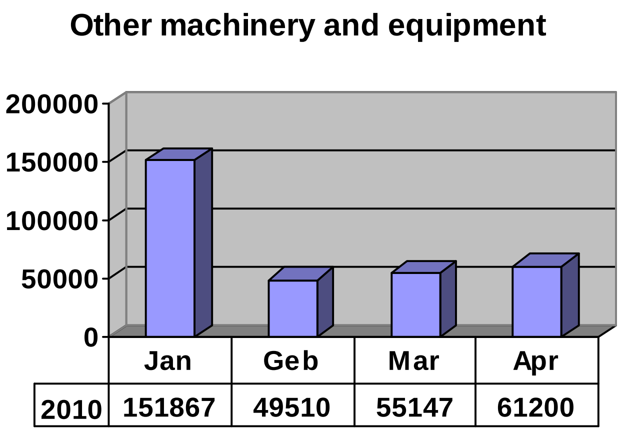


Fig.12 Incomes of 2010 in a month

Comparing table 6, where quarters of 2009 are shown, and in table 4 we can see that the indexes in 2009 and 2010 are better than in 2005. According to first months of the 2010, the 1st Qtr shows that incomes were 2 56 524, it increased by 45 % comparing with 2009 1st Qtr, it is the biggest quarter comparing all years which has been analyzed, so we can presume, that this industry is growing up again.

3.3.Analysis of written questionnaires results

3.3.1. Sample size and confidence interval calculation

During investigation it is important to determine the minimum number of participants, in order to make meaningful conclusions. It is necessary to determine the sample size.

In statistics, ***a sample*** is a subset of a population. Typically, the population is very large, making a census or a complete enumeration of all the values in the population impractical or impossible. The sample represents a subset of manageable size. Samples are collected and statistics are calculated from the samples so that one can make inferences or extrapolations from the sample to the population. This process of collecting information from a sample is referred to as sampling. [33]

The ***sample size*** of a statistical sample is the number of observations that constitute it. It is typically denoted *n*, a positive integer (natural number). [36]

The larger sample size is, it is surer that answers truly reflect the population (in this case: enterprises). This indicates that for a given confidence level, the larger sample size, the smaller confidence interval.

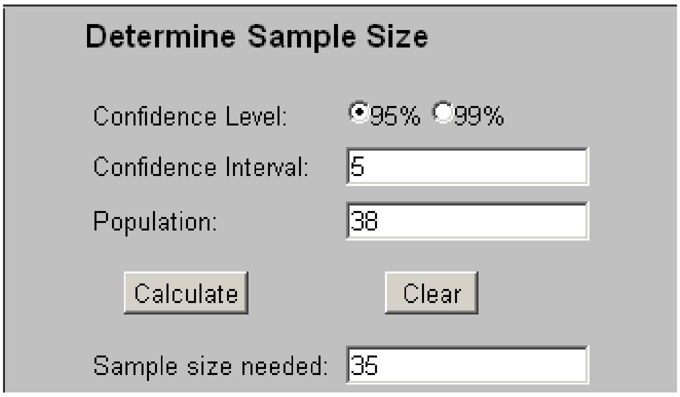


Fig. 13 Sample Size Calculations

Sample size for the collecting data of the main selected sector is 35 enterprises.

Confidence Level is expressed as a percentage and represents how often the true percentage of the population who would pick an answer lies within the confidence interval. The 95 % confidence level means you can be 95 % certain. [36]

Confidence Interval (also called margin of error) is the plus-or-minus figure. The margin of error is the amount of error that you can tolerate. Lower margin of error requires a larger sample size.

Population size represents how many enterprises are in the selected group research. Regarding Lithuanian Development Agency it was 38 industrial enterprises of selected sector – Manufacturing general purpose – Non-domestic cooling and ventilation equipment production.

Using Sample Size Calculator it was evaluated Confidence Interval: *c=10.28*

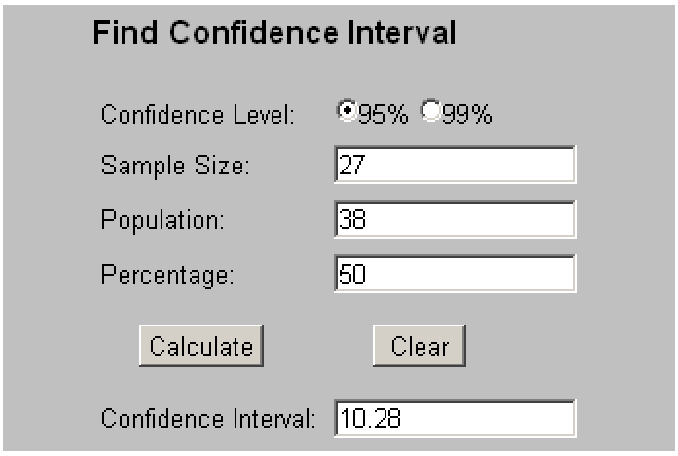


Fig. 14 Confidence interval Calculation

Sample size and Confidence Interval have been calculated with a help of Sample Size Calculator. [16]

3.3.2. Data collection scheme

The data collection for a survey consists of three phases in order to get useful information from more sources that match my criteria. Fig. 4 shows the phases from where information must be gathered.

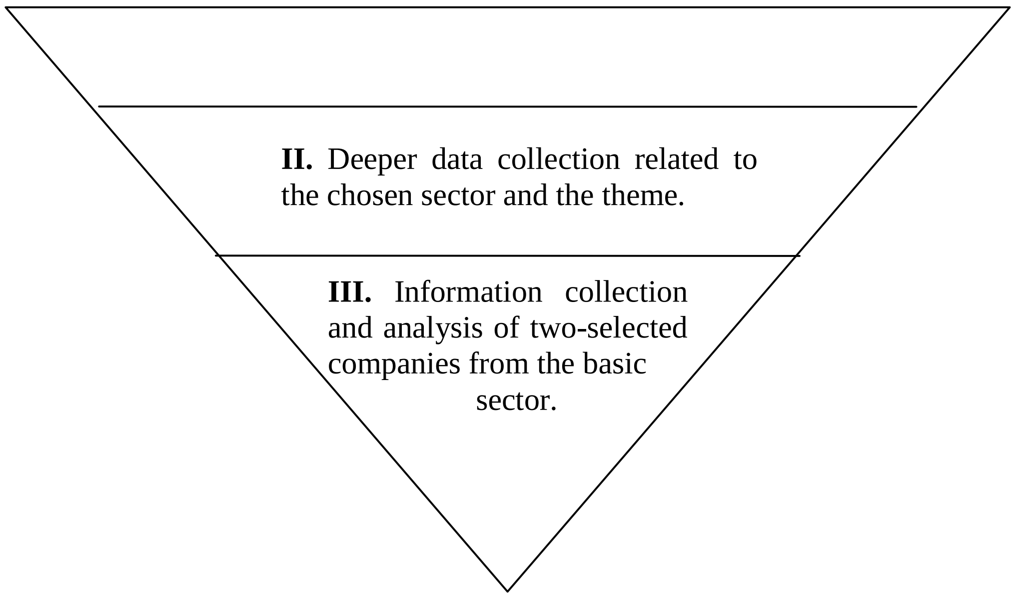


Fig. 15 Phases from which information must be gathered

Phase I. Brief data collection and analysis of comparable sector into the selected

I choose one more sector which would be similar to the main chosen to make brief analysis in order to know the spread of Kanban system. The additional sector is chosen considering its activities, product range and used components. It would be – Manufacture of fabricated metal products, except machinery and equipment, more specific – Manufacture of structural metal products.

Table 8 Specific features

Non-domestic cooling and ventilation equipment production	**Manufacture of structural metal products**
Activities	
Enterprises which has similar manufacturing operations: bending, punching, welding, drilling, cutting, painting, assembling, packing,	
Product range	
Products which is made from similar raw material: aluminium, steel; different designs and variations of the products.	
More specific	
Enterprises which are making products from aluminium o steel, produce not heavy construction products, which have similar machinery,	

For the collection this data telephone interview has been used. 17 enterprises (sample size) were surveyed with a help of the interview in order to find out whether they use the Kanban system or have heard about it. Figure 2 shows the results of the interview. Most of the respondents, in the enterprises, were people who are related with production. Results show that most of respondents do not use or even have not heard anything about the Kanban system (61% of enterprises), less then half of the interviewed enterprises heard about this system (29%), and just couple of enterprises is using this system (10%).

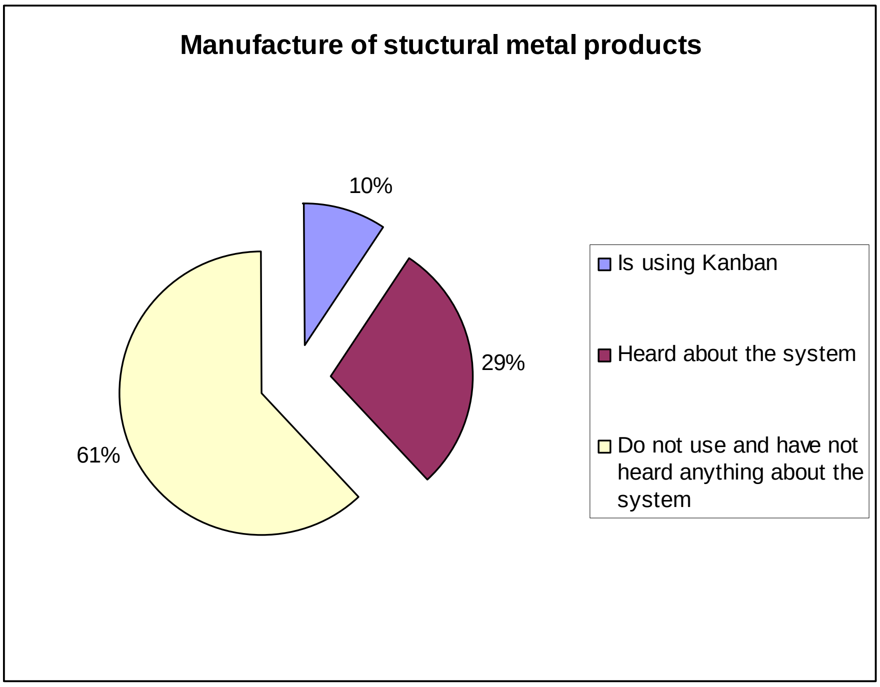


Fig. 16 Distribution of the Kanban system

Phase II. Deeper data collection related to the chosen sector and the theme

The questionnaire was prepared for the enterprises (couple questionnaires were prepared in the second research work, later it was a little bit changed/improved and structured into one questionnaire, see appendix 5) to clarify the prevalence of Kanban system in chosen sector and to analyse the main problems faced by enterprises. During survey a questionnaire was sent by e-mail and telephone interview. A questionnaire is given in appendix 3.

The purpose of this interview is to provide accurate, comprehensive information about existing problem and to make analysis of it.

Phase III. Information collection and analysis of two-selected companies from the basic sector

I choose two companies which belong to the same industry sector. One of the companies has Kanban system in some of the areas and still is implementing it; other companies do not have this system but have heard and knows about it. One company is producing product in UK other one in Lithuania.

3.3.3. Questionnaire results analysis

Analysis is made when data is collected during empirical research time. In order to show the results were used charts, tables, data processing program such as SPSS (a computer program used for statistical analysis – Statistical Package for the Social Sciences).

The survey was guided by the principle of non-quantitative, but qualitative survey.

Questionnaires were sent by email, but because it is not the most effective way to make a survey, also a telephone interview has been done. Moreover, some of the respondents were interviewed individually – deep interviews. These interviews were done in the enterprises, where this was the main analysis of the research.

According to sample size, it was 35 respondents (enterprises) who were including in this survey and 22 of them answered in some of my questions.

Moreover, individual persons were interview in company TROX UK Ltd. in order to know how they evaluate existing Kanban system in their company. A total 17 people where interviewed, because not all the people are working close to this system.

In order to make analysis with a help of SSPS computer program was used Kruskal-Wallis and Man Whitney criteria's, correlation with a Spearman's correlation criteria, also chi^2- value and p-value.

In statistics, the Kruskal-Wallis one-way analysis of variance by ranks is a non-parametric method for testing equality of population medians among groups. [34]

In statistics, the Mann-Whitney U test is a non-parametric statistical hypothesis test for assessing whether two independent samples of observations have equally large values. [35]

Spearman's rank correlation coefficient is used to investigate the relationships that may exist between the two ascending or descending lined variables.

A chi^2 test (χ^2 – test) is a statistical hypothesis test in which the sampling distribution of the test statistic is a chi-square distribution when the null hypothesis is true, or any in which this is asymptotically true, meaning that the sampling distribution can be made to approximate a chi-square distribution as closely as desired by making the sample size large enough. [5]

The p-value in statistical is the probably of obtaining a test static at least as extreme as the one that was actually observed, assuming that the null hypothesis is true. One often "rejects the null hypothesis" when the p-value is less than 0.05 or 0.01. When the null hypothesis is rejected, the result is said to be statistically significant. [6]

During the survey it was tried to find out what is dominating size of the companies in this sector. The results showed that most, namely the 15 (68.2 %) companies employed between 11 and 50 workers, 5 (22.7 %) – 51 to 250 employees and 2 (9.1 %) – from 1 to 10 employees (fig. 17).

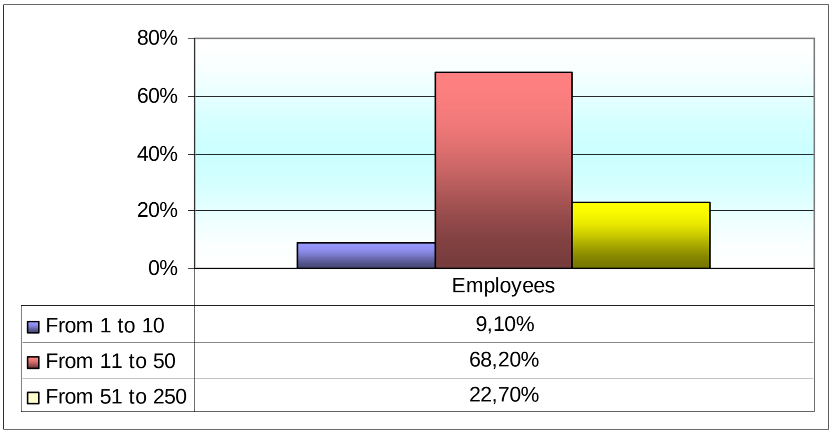


Fig. 17 The number of employees in enterprises

The largest part of the production in the companies takes standard items (40.9 %), mixed production (31.8) and non-standard products (27.3) (Fig. 18).

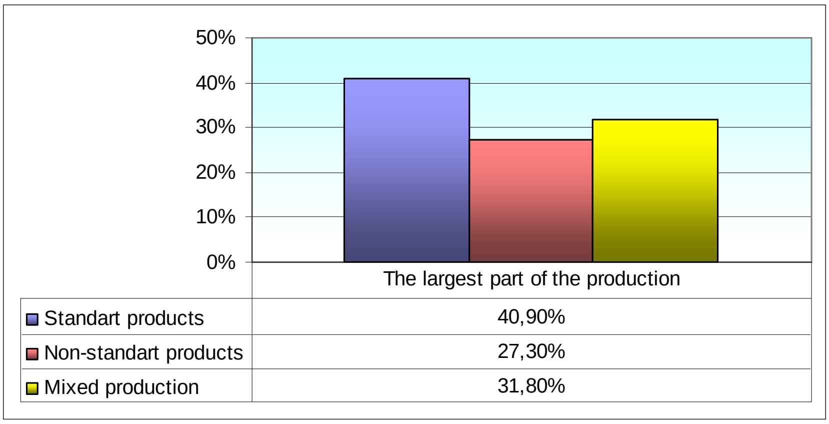


Fig. 18 The largest part of the production

One of the important things in the research work was to find out what are the problems that companies faces in most cases. Table 9 shows that the most important problem to the least important. We can see that the main problem is material management problems, then additional production costs, after it, inventory management problems, information supply problems, storage problems, then quality problems, and two new one, which respondents mentioned, low attention to details and lack of trained workers. In order to determine exactly between which problems are statistically significantly differences is used Mann-Whitney criteria. The results showed that problems of “Low attention to details” and “lack of trained workers” are less important that others, which are mentioned before.

Table 9 Problems that companies faces

Problems	Minimum value	Maximum value	M ± SD
Material management problems	2	4	2,82± 0,664
Additional production costs	1	4	2,50 ± 1,102
Inventory management problems	1	4	2,41 ± 0,854
Information supply problems	1	4	2,36 ± 0,902
Storage problems	1	4	2,32 ± 0,894
Quality problems	1	4	2,23 ± 0,869
Low attention to details	1	3	1,14 ± 0,468
Lack of trained workers	1	3	1,09 ± 0,426

The study aim is to determine if the problems are different in the companies which highest part of the products takes standard products, non-standard products or mixed production. Setting the Kruskal-Wallis criteria set out statistically significant differences among the three companies, storage problems (chi^2=8.842, p=0.012, $p<0.05$) and information supply problems (chi^2=6.821, p=0.033, $p<0.059$ (Table 8).

In order to find out exactly which enterprises are among the statistically significant differences is used Mann-Whitney criteria. The results indicate that significantly different enterprises which produce the highest proportion of standard products and enterprises with the largest share of production in non-standard products, storage problems and statistically significantly different enterprises which produce the highest proportion of evaluation of storage problems (z=-2.725, p=0.006, $p<0.01$); and enterprises with the largest share of mixed production in manufacturing evaluation of storage problems (z=-2.349, p=0.023, $p<0.05$). In the enterprises with the highest standard of the standard products the problem is less relevant.

In addition, statistically significantly different enterprises, which produce the highest proportion of standard products and enterprises with the highest share of production in non-standard products information supply problems estimates (z=-2.331, p=0.020, $p<0.05$); and statistically significantly different enterprises which produce the highest proportion of standard products and enterprises with the largest share of mixed production in manufacturing information supply problems estimates (z=-2.059, p=0.039, $p<0.05$).

\

Table 10 Enterprises that differ according to who are the largest part of production problems in the statistical significance of differences (by Kruskal-Wallis test)

Problems	Enterprises, where the biggest output consists of	Average rank	chi² value	*p*-value
Inventory management problems	Standard products	10,17	0,746	0,689
	Non-standard products	12,67		
	Mixed production	12,21		
Storage problems	Standard products	6,83	8,842	**0,012***
	Non-standard products	14,33		
	Mixed production	15,07		
Additional production costs	Standard products	8,67	3,092	0,213
	Non-standard products	13,42		
	Mixed production	13,50		
Material management problems	Standard products	9,28	2,222	0,329
	Non-standard products	13,17		
	Mixed production	13,50		
Information supply problems	Standard products	7,39	6,821	**0,033***
	Non-standard products	14,67		
	Mixed production	14,07		
Quality problems	Standard products	10,11	0,877	0,645
	Non-standard products	12,00		
	Mixed production	12,86		
Low attention to details	Standard products	11,78	0,804	0,669
	Non-standard products	10,50		
	Mixed production	12,00		
Lack of trained workers	Standard products	12,22	1,444	0,486
	Non-standard products	11,00		
	Mixed production	11,00		

The differences were statistically significant, * when $p < 0,05$, ** when $p < 0,01$, *** when $p < 0,001$

Respondents were asked whether they were familiar with Kanban production control system. The results showed that just half of the subjects (50 %) do not know anything about this system, less then a third of the respondents (31.8 %) heard something about this system, and 18.2 % of the enterprises are familiar with this system (Fig.19).

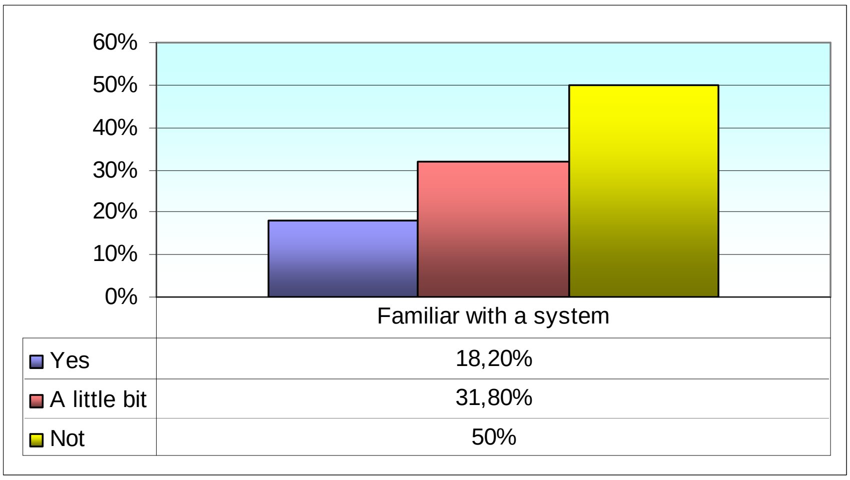


Fig. 19 Familiarity with the Kanban production control system

Respondents were asked weather their company has implemented Kanban production control system. The results showed that 19 (86.4 %) enterprises do not have this system in their enterprises, 2 companies (9.1 %) are trying to install it (currently is being implemented) and 1 (4.5. %) has this system.

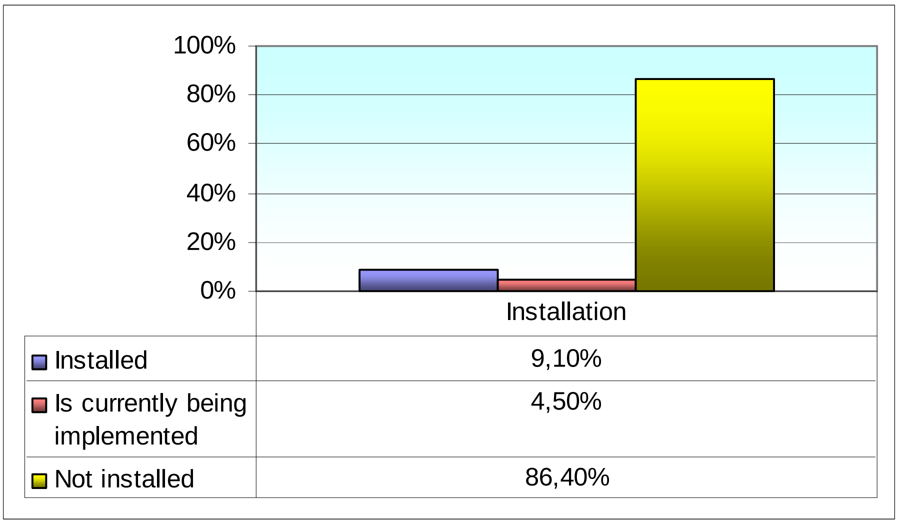


Fig. 20 Kanban system implementation

Other important thing was to find out what are the advantages and disadvantages of the Kanban system.

Table 11 shows that, from largest to smallest, the benefits are distributed as follows: it provides flexibility in production, improves the flow of production, optimize inventory and reduces product obsolescence, reduces total cost, reduces the amount of waste, increases output, better machine utilization. By Kruskal-Wallis criterion set out a statistically significant difference between the expression of these advantages ($chi^2 = 11.342$, $p = 0.078$, $p > 0.05$).

Table 11 Advantages of the Kanban system

Advantages	Minimum value	Maximum value	M ± SD
Provides flexibility in production	0	1	0,55 ± 0,522
Improves the flow of production	0	1	0,55 ± 0,522
Optimize inventory and reduce product obsolescence	0	1	0,36 ± 0,505
Reduces total cost	0	1	0,36 ± 0,505
Reduces the amount of waste	0	1	0,27 ± 0,467
Increases output	0	1	0,18 ± 0,405
Better machine utilization	0	0	0,00 ± 0,000

Table 12 shows that, from largest to smallest disadvantages are distributes as follows: slow to react to changes in demand, difficult to understand the system, the system is expensive, inefficient system. By Kruskal-Wallis criterion set out a statistically significant difference between the expression of these disadvantages ($chi^2 = 6.989$, $p = 0.072$, $p > 0.05$).

Table 12 Disadvantages of the Kanban system

Disadvantages	Minimum value	Maximum value	M ± SD
Slow to react to changes in demand	0	1	0,55 ± 0,522
Difficult to understand the system	0	1	0,18 ± 0,405
The system is expensive	0	1	0,18 ± 0,405
Inefficient system	0	1	0,09 ± 0,302

Enterprises, where Kanban production control system has been installed and is currently installed, was asked what are the main difficulties they faced installing: enterprise said that it was difficult because of the long duration of implementation, other enterprise claimed that because of the lack of information about the system and because the workers hardly knew why the system is required and it was difficult for them to understand.

Also, it was several companies where Kanban production control system has been installed and is currently installed (total 3); was asked how long it took to install it: 2 companies said that to install such a system lasted from 7 to 9 months and one enterprise claimed that such a system lasted to install from 4 to 6 months.

Enterprises, which Kanban production control system is installed (total 2) were asked what has changed after the installation: 1 enterprise claimed that it improved inventory flow; other enterprise claimed that it improved production flow.

3.3.4. Regression and correlation analysis

Regression analysis involves indentifying the relationship between a dependent variable and one or more independent variables. A model of the relationship is hypothesized and estimates of the parameter values are used to develop an estimated regression equation. [7]

Regression model. In simple linear regression, the model used to describe the relationship between a single dependent variable y and a single independent variable x is y = $a_0 + a_1x$ + k. a_0 and a_1 are referred as a model parameters, and is a probabilistic error term that accounts for the variability in y that cannot be explained by the linear relationship with x. if the error term were not present, the model would be deterministic; in this case, knowledge of the value of x would be sufficient to determine the value of y. [33] When x is increasing and in the same time y is increasing then connection is called positive. When x increases y decreases the relationship is negative. It is easy to determine when the connection is functional.

Correlation. Correlation and regression analysis are related in the sense that both deal with relationships among variables. The correlation coefficient is a measure of linear association between two variables. Values of the correlation coefficient are always between -1 and +1. A correlation coefficient of +1 indicates that two variables are perfectly related in a positive linear sense; a correlation coefficient of 1 indicates that two variables are perfectly related in a negative linear sense, and correlation of 0 indicates that there is no linear relationship between the two variables. [7]

The empirical correlation coefficient is calculated by equation give below: [7]

$$r_{xy} = \frac{\sum\left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right)}{(n-1)s_x s_y}, \qquad (1)$$

where $\bar{x}$ and $\bar{y}$ are the sample means of *X* and *Y*, s_x, and s_y are the sample standard deviations of *X* and *Y* and the sum is from *i=1* to *n.*

Coefficient of determination is equal to the square of correlation coefficient and it indicates the percentage considered a factor which explains the dispersion of the values of the regression equation. This ration indicates whether a stochastic relationship between y and all the relevant factors is.

This regression and correlation analysis has been done in order to know how employees in plant evaluate Kanban system operation and the factors which influence it.

In order to know if Kanban system is good as a visual management system to use in the plant we have to know the employees satisfaction of this system and that satisfaction depends of the visuality level.

It is understandable that if the visuallity in the plant as it supposes to be it reduces employee's satisfaction with the existing system. Regression analysis results are presented in the fig. 21.

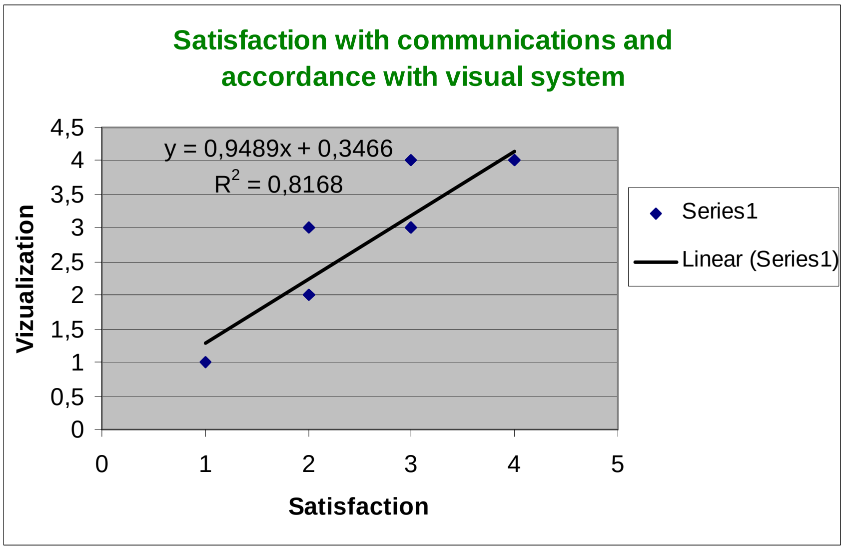


Fig. 21 Relationship between the employee's satisfaction and system's visualization

The regression coefficient of this relationship R = 0,9037, Coefficient of determination R^2 = 0,8168. The connection is positive.

Correlation analysis between relationship how is easy to understand the system and its effectiveness, see fig. 22. As we can see, if it is easy to understand the Kanban system it will work effectively. The regression coefficient of this relationship R = 0,8490, Coefficient of determination R^2 = 0,7945. Connection is positive.

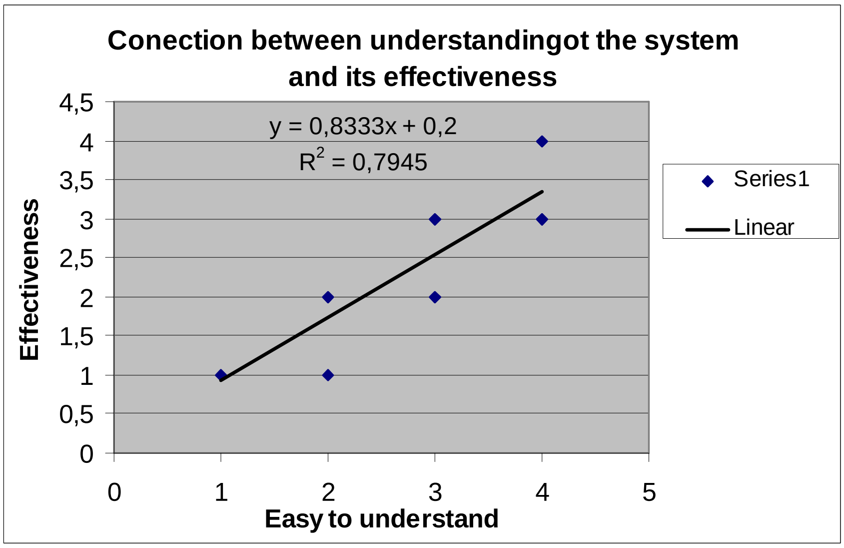


Fig. 22 Relationship between systems effectiveness by easiness to understand it

One more correlation analysis has been done between the relationship of the scheduling system and its necessity in the plant, see fig.23. As chart shows it is big necessity of the scheduling system if it works as it has to. The regression coefficient of this relationship R = 0,8454, Coefficient of determination R^2 = 0,7147. Correlation is positive.

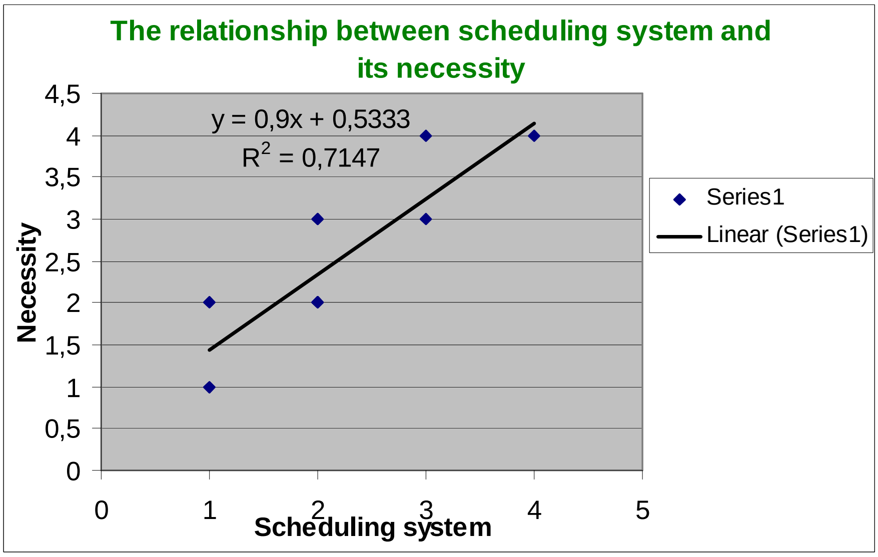


Fig. 23 Relationship between the scheduling system and its necessity

According to all correlation values of chosen aspects we can see that it is quite strong relationship between it. It is natural and understandable, because these chosen criterions are very important in successful operation of the Kanban system.

3.4. Analysis of Kanban system implementation in industrial enterprises

I choose two companies which belong to the same industry sector and match my criteria in the investigation. One of the companies has Kanban system in some of the areas and still is implementing it; other company does not have this system but has heard and knows about it. One company is producing product in UK other one in Lithuania.

These two companies are identical, because of the exactly the same industry, all the structure, the size of the company, product range, used machines and operations which there are producing, number of employees. I think that comparing these two similar companies is good chose in order to find out if the Kanban system could be implemented in such a type of industry and what benefits it can bring.

Table 13 The main specific features of enterprises

Enterprise	**TROX UK Ltd.**	**UAB Salda**
Activities	Production of heating and ventilation systems	Production of ventilation equipment.
Number of Employees	51-250	51-250
Products	Grilles and Diffusers, Filters, VAV/CAV, Dampers, Attenuators, FCU, Multi Service Chilled Beams, Fan Coil Units, Integrated Service Modules, High Density IT Cooling, Decentralised ventilation, Standard Chilled Beams	Fans, Air handling units, Air handling units with heat recovery, Heaters and coolers, Controllers, Ducts and fittings, Ducts and fittings for dust extraction
Used machines/operations	Brake presses, double mitre saw, welding robots, powder paint-finish line, roll forming machines, panel folding machines, guillotines, flanging machines, rock-wood & foam cutting saws, power presses, punching centre machines and etc.	Speed laser and plasma cutting, hydraulic punching, high accuracy press brakes, eccentric and deep drawing presses, heavy-duty spinning, powder coating, spot welding, clinching, roll forming, flanging machines and etc.
Product/Service Description	Manufacturing and service industry	Manufacturing and service industry
	Non-domestic cooling and ventilation equipment production	

3.4.1. Analysis of Kanban system implementation in TROX UK Ltd. enterprise

TROX UK Ltd. is apart of the TROX Group headed by Trox GmbH (Germany) which is the founding company. It is a leading designer and manufacturer of HVAC (Heating, Ventilating, and Air Conditioning) and building services solutions with over 50 years experience in the industry. It was established in Thetford, England in 1962 (United Kingdom).

The TROX UK manufacturing philosophy is based upon for critical factors that influence the success of manufacturing enterprise.

- Continuous Improvement
- People Focus
- World-beating Production Practices
- Investment

Company has TROX Production System (TPS) which is based on Toyota's manufacturing 5 fundamentals and 14 tools. Lean Manufacturing is being introduced through the production areas, it includes Kanban System. Kanban system in some of the sectors in the workshop and company is still looking for other sectors where they could install it. TROX (U.K.) Ltd is trying to achieve Single Unit Flow which will reduce Work In Progress (WIP), waste and Lead-times.

The plant of implementation process and all phases which I make analysis of the implementation process in this work are chosen for a product – Floor Grills (AFG). This product is in the second place, after Chilled Beams, according to the customers demand in the company. The type AFG floor grille has been specifically developed for mounting in Raised Access Floors in such areas as Computer Rooms, where load and damage resistance of the utmost importance. Having a heavy duty construction, the AFG can replace 600 mm square floor tiles to handle supply air or alternatively extract air. Grille border depth can be specified to suit the type of floor system used. A range of surface finishes is available.

Summary of the Kanban system implementation process for Trox UK Ltd., see appendix 4. It was created action plan where all necessary steps have been set in a certain period of time to reach the purpose. Was created the period of time was set for the implementation process of the Kanban System was planned that it will take **23 weeks** (8 months). During this time some problems for implementing this system process **7** weeks longer, so the occurred implementation process took 30 **weeks** (7.5 month). All the problems and the reasons why these problems occurred are shown in this table. There problems occurred mainly because lack of information was given and employees in workshop, who worked in the company for a very long time, had a pessimistic attitude to a new system.

Detailed implementation process phases of the Kanban system implementation process:

I. Phase – Current state analysis.

Steps which were made in this phase:

1. Gathering data of sales demand over the last two years.
2. Analysis of the data – demand pattern/average demand.
3. Establishment of the existing process route & material flow.
4. Chart of the existing process – current state analysis.

Planned time for the phase: 7 weeks; has been done in a period of 8 weeks.

Problem: obstacles to obtain statistical data.

Reason: lack of information between the departments.

Problem solving: searching for the information in all departments which could have important information; better communication with colleges by explaining them why this importation is very important and what it could change in the company.

Summary of this phase.

Floor grille is one of the standard products in the company. It is the product from the Grill & Diffusers product group. The quantity of this product each year, month is different, it depends of the costumer demand. According this I made the analysis of production demand analysis which gives the necessary information about the amount of production. Prospected analysis was calculated based on information obtained from TROX UK Ltd company. This analysis is made in accordance with a plan of manufacture of details for a month. The amount of produced details is monthly demand of production.

Table 14 Date of the needed demand

AFG	January	February	March	April	May	June	July	August	September	October	November	December	monthly average	weekly average	daily average
AFG - 2008	0	537	0	208	49	100	88	176	1211	52	71	0	208	52	10
AFG - 2009	138	831	8	91	23	70	91	3	11	151	46	16	123	31	6
Average	69	684	4	150	36	85	90	90	611	102	59	8	165	41	8

Table 14 presents a monthly demand over the last couple years of AFG products. Columns in the table show the quantities of products that were produced each month.

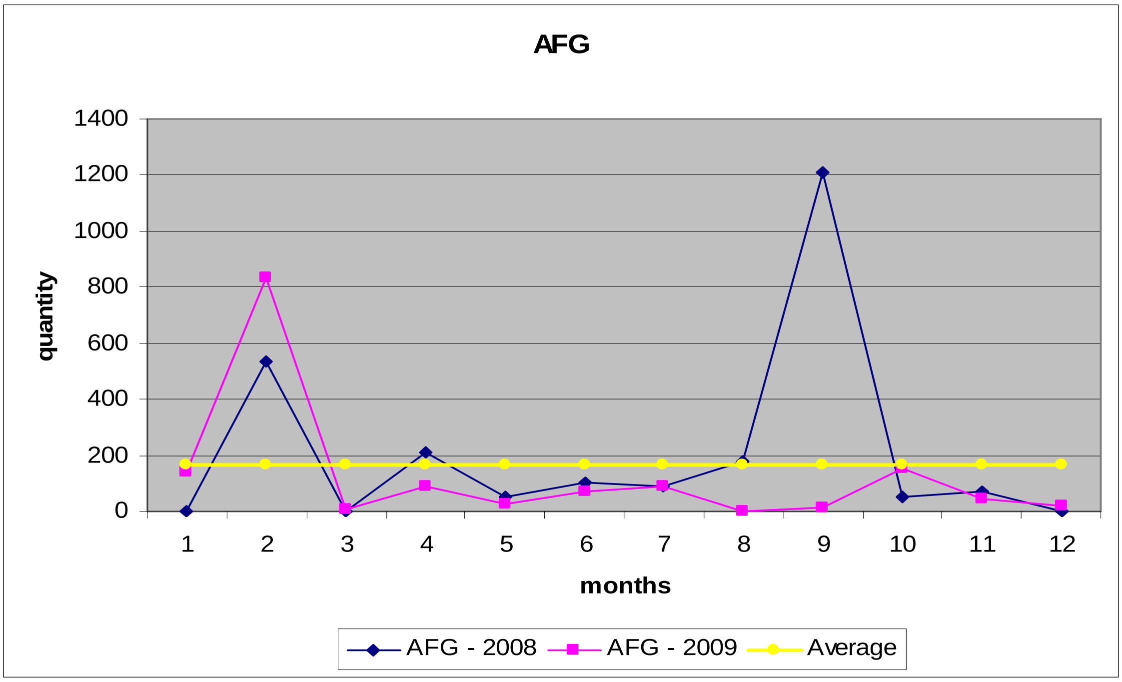


Fig. 34 Chart of the product AFG demand

Fig. 24 presents a chart of the product AFG demand. We can see that demand of the product is different each year and month. Yellow line in the chart shows the average demand of each month; it is 165 products in the month. Moreover, it is a season demand during first three month of the year, from January until March.

According to the date needed demand and chart of the product AFG demand I take that the average quantity of products manufactured for a month is 165.

Also the production process was stated: operations of the production process, cycle times of each operation, the current number of employees for each operation and changeover times of each operation are shown in current state Value Stream Map, see fig 26.

The Current Value Stream Map was created that would be visually displayed production flow in the factory including delivery to costumers and received material resources from suppliers. Current Value Stream Map is based on the product manufacturing process “from door to door”. This process includes: the provision of basic material resources and finished products shipment to customers.

II. Phase – Preparation for a new system.

Steps which were made in this phase:

1. Establishment if the Baan BOM structure supports Kanban.
2. Examination of the options for changing the structure to support Kanban.
3. Establishment of desired transfer batch size and specify pallet size.
4. Produce factory layout defining Kanban locations quantity & positions.

Planned time for the phase: 9 weeks; has been done in a period of 10 weeks.

Problem: Baan system (system which helps to plan and organize the production in the enterprise). It was difficult to find a person who could know how this system works what this system could support a Kanban. Two people in the company can make configuration with this system.

Problem Solving: Communication with responsible people who can configure the system by explaining couple times how it is important that Kanban system could run smoothly by supporting of the existing system.

Summary of this phase.

Baan system support to Kanban system and possibilities of changing the structure were analyzed and estimated by IT (Information Technology) department support in the company. They change the system that it could support new one by making reconfigurations with it.

Desired batch size was considered to the production monthly and daily demands according to an analysis which was made in phase-I of the implementation process and pallet size was specified according to it. Because the production process is simple and the flow is always the same to calculate the Kanban size is very simple, it was calculated by using Excel sheet, see appendix 5. The main formula was used to make calculations is described earlier in this work, see chapter 2.3.1.

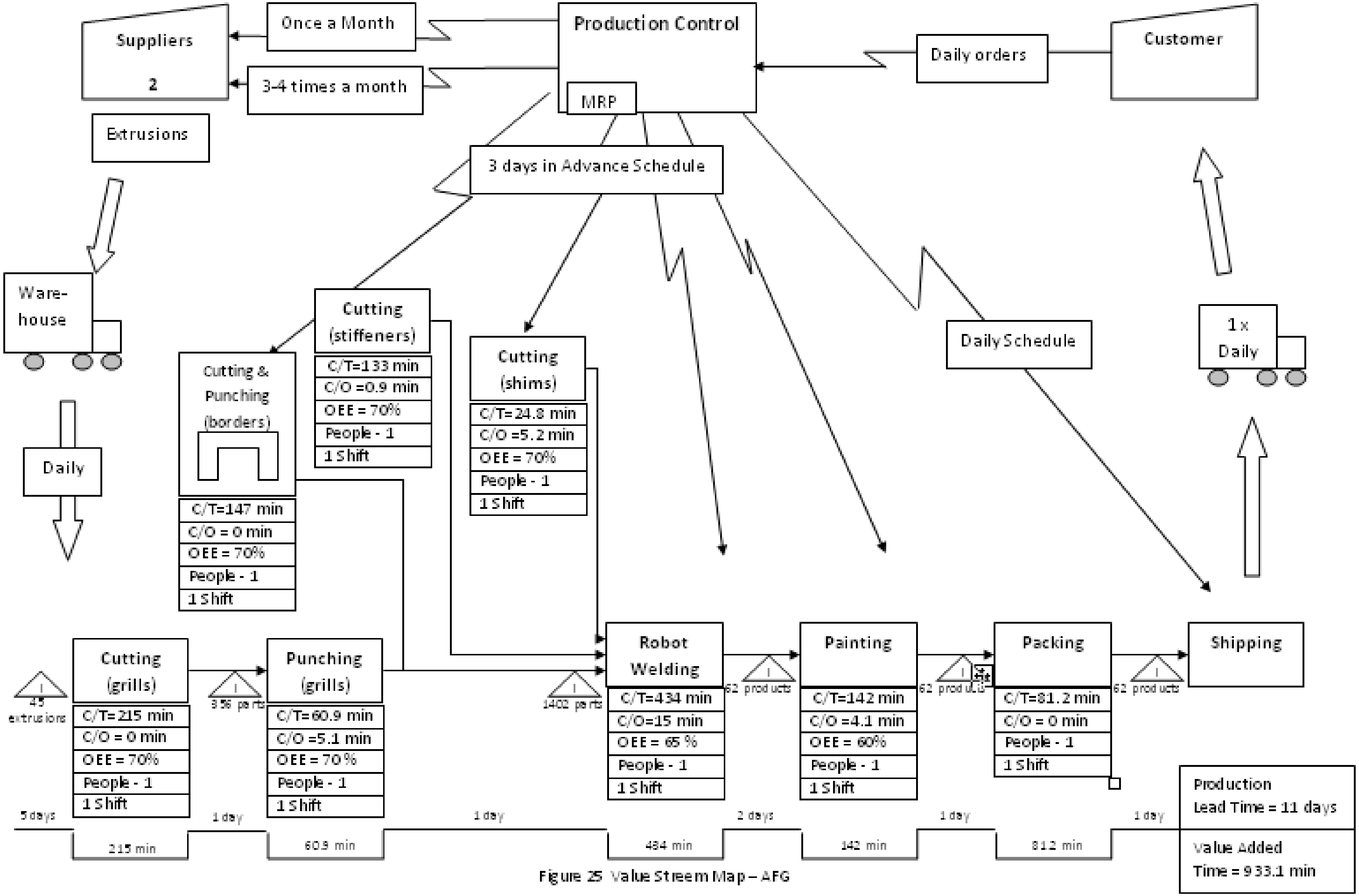


Figure 25 Value Stream Map – AFG

The layout defining Kanban locations, see fig 26. In the layout is shown five work stations and the places where Kanban trolleys/bins are planned to be, it does not represent all the factory, because it is concentrated just in these operations where Kanban suppose to be. Moreover, we can see the flow of the destination.

III. Phase: Design and implementation of the process.

Steps which were made in this phase:

1. Design and order suitable containers.
2. Marking the floor with locations & bins with part data.
3. Drawing up an SOP for Kanban process.
4. Education of those involved in the re-supply rules
5. Running of the system & monitor it.

Planned time for the Phase: 7 weeks; it has been done in the period of 12 weeks.

Problems: First created design of the bins was bad one, because of quality issues; the quality department was not involved in the designing process. Also, suppliers run out of the material, so they could not deliver ordered bins for the Kanban system on time. Moreover, during the education about this system employees had a pessimistic approach about this new system. In the end it was hard to start running of the system, because of the problems of controlling it in proper way, because the workers could work in proper way. Some of the them time by time forgot to change the card in Kanban board to show visual sign what kind of parts it is necessary to start manufacture of and the quantity of it; using the containers even if it was not empty till the last part; some of them forgot where containers has to stand even if the floor marking is done.

Solving of the problems: in the designing of the bins or trolleys for the products that you want to set for the Kanban all main departments which are concerned with a production in the plant have to be involved (production engineers, development engineers, design engineers and quality inspector).

In order to change a view of the employees who had to control the system in the workshop was couple educations used by trying them to explain why this system is so important to use in the company and what changes it will make for a plant. Controlling problems has been solved in similar way as changing the bad view about the system; it was explained many times how it has to work in order to achieve the goals.

Summary of the phase

Containers where design according the size of the products and material parts; the quantity which had to be in it and the weight of the material. The floors were marked to show the location for the containers where they have to stand as a visual sign, also as one of the 5s requirements.

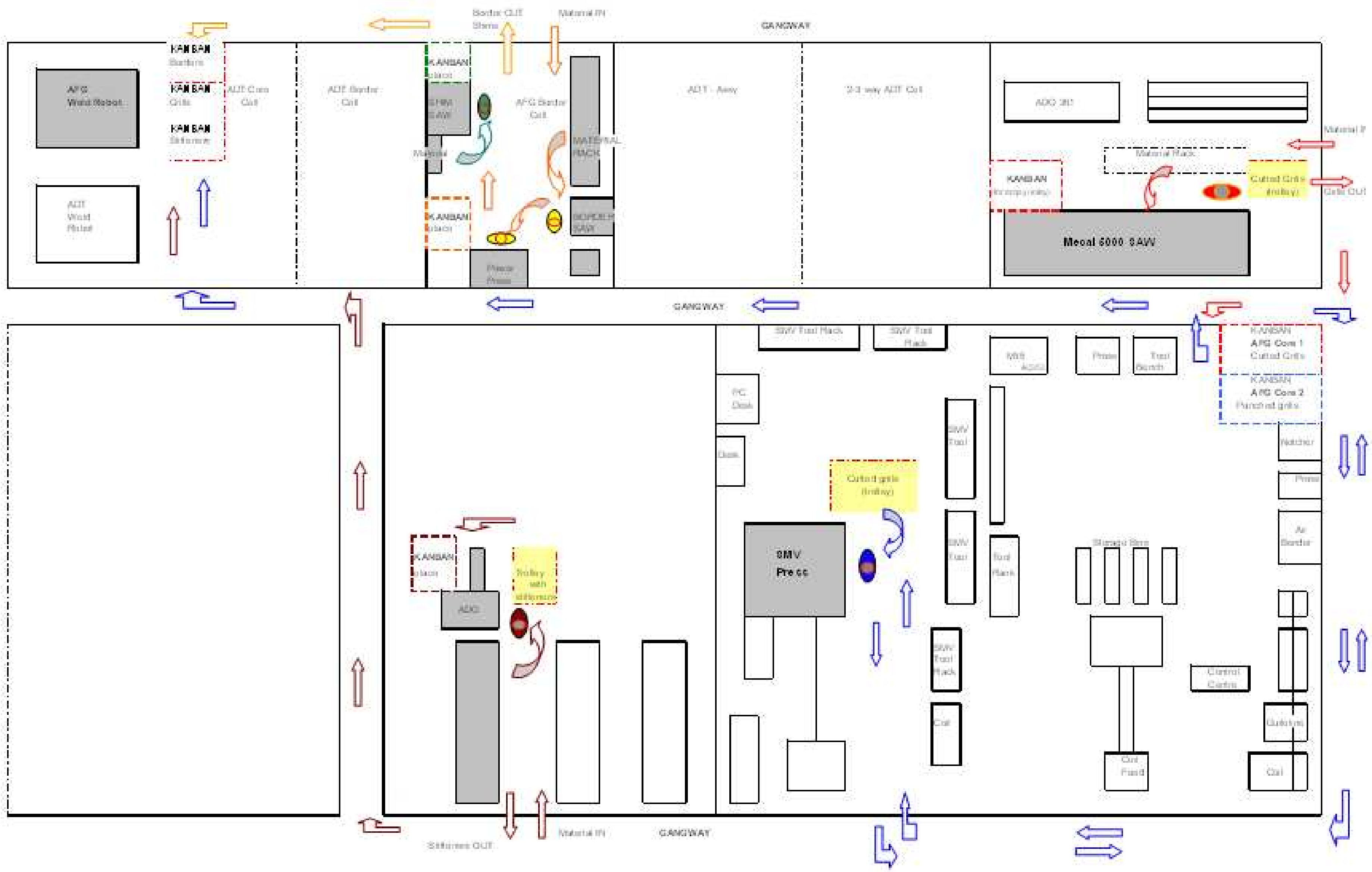


Fig. 26 Layout defining Kanban locations

To know how the Kanban system process works in workshop the SOP (Standard Operation Procedure) was drawn up which explains how to use the Kanban cards and the board of it, see appendix 6. This procedure is included in the education of other employees who would be involved to run and control the system. Everybody has to understand the main rules of this system in order to run it smoothly. After everybody understood the purpose of this system and had a view how it works the system is started to run and in the same has to be monitored if it is running without any problems and mistakes that in the future it would be possible to improve it.

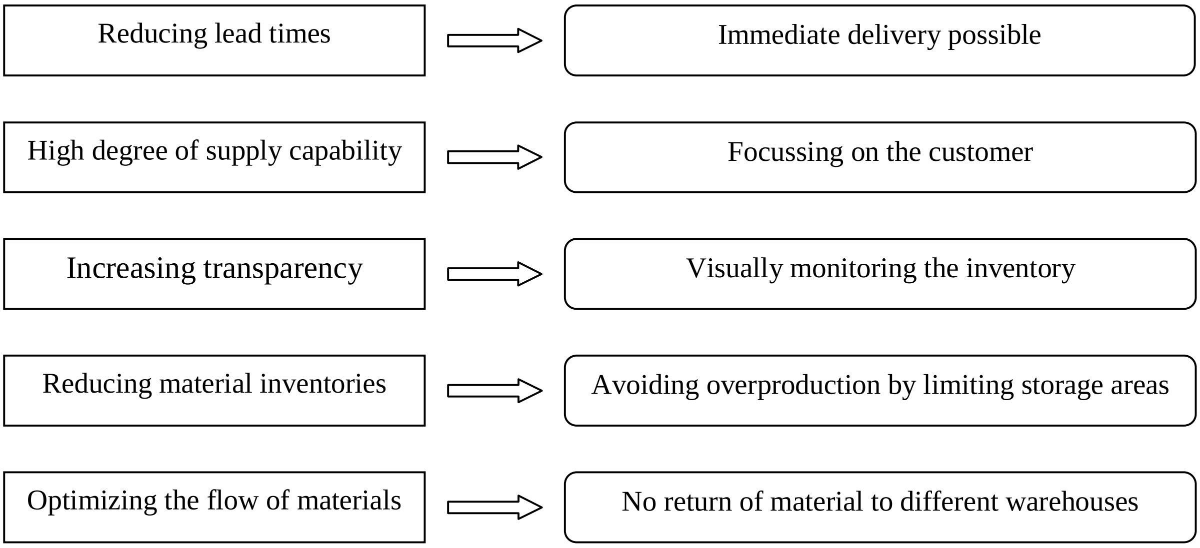


Fig. 27 Goals and benefits of the Kanban system in TROX UK Ltd.

The goals which Kanban system has to reach have been set in the enterprise, and the benefit which was has been made. Due to the introduction of the Kanban system essential key performance indicators were positively developed. We can see

- Reduced lead times in order the deliver of the goods is possible immediate. After using Kanban, the production lead time decreased from 11 days till 5,5 days, it decreased by 50 %, see current value stream map, which shows the existing situation in the plant according chosen product (fig 29). Also, existing situation after implementing the system shows value stream map (fig. 28).

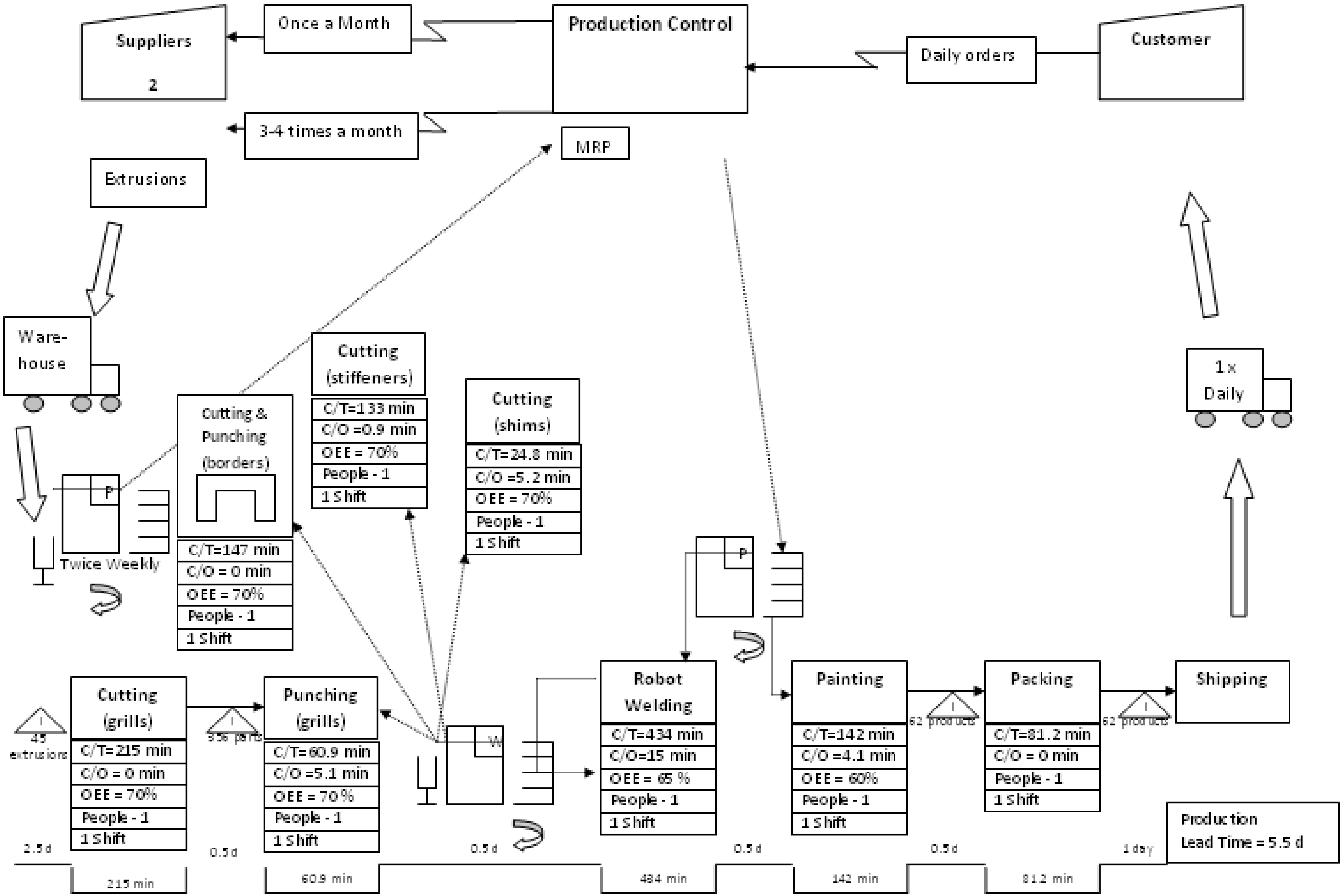


Fig 28. Current Value Stream Map

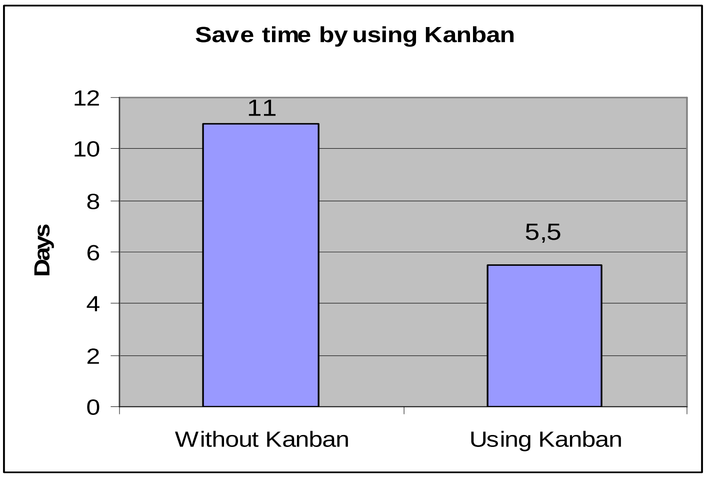


Fig. 29 Saving time by using Kanban

- High degree of supply chain higher deliverability by focussing on the customer demand.
- Increase transparency of production processes by visual and self controlled process (faster problem solving, simple for employee, increase of availability of parts); Kanban is able to show problems but can not solve them.
- By reducing material inventory the space saving increased by low inventory levels in the plant. Greater control and space savings (reduce floor space).
- Optimizing the flow of materials by making short inventory time and smaller inventory stocks that reduced inventory costs, no waist (overproduction, waiting times). Waiting times before the system was at least in each station 1 day.

After all period of the implementation process and training how the system works, at the moment where no any big problems or mistakes are by running this system. Of course in the future all the time it has to be improved. Trox UK Ltd is trying further to implement Kanban system in other aeries of the plant, in order to improve the inventory management and its flow.

3.4.2. Analysis of the ability to use the Kanban system in UAB Salda enterprise

UAB Salda – is a Lithuanian leader in production of ventilation equipment, with 19 years of experience in the field. The company produces a wide range of equipment for ventilation systems. “Salda” has grown up investing in modern technologies and equipments. Barono TŪB “Salda” was established in Šiauliai, Lithuania in 1990.

UAB Salda, is always investing in modern technologies and equipments so this company is interested in different organization and management system in the production, so this company is interested in Kanban system too, just they do not have it yet. According the information, which will be collected from a company associated with the Kanban system installation options will be analyzed and represented in the final work.

Reasons why should UAB Salda implement Kanban system

- Could reduce the production and raw material stocks. Enterprise has big inventory levels of raw material and prepared parts. Items are standing in WIP (Work in Process) stage, it are not completed, being fabricated and waiting in the buffer storage.
- The system could help to detect manufacturing defects; it happens that situation occurs during the operations wrong part for producing a product is used, or because a material/part is without a tag or wrong information.

There are some obstacles why this enterprise has not implemented the system in the plant:

- There is a risk if the work is incomplete or will not bring any benefits for the plant;
- Well-established manufacturing organization practice can not react to the Kanban installation system requirements and associated changes.

To evaluate the Kanban system performance in UAB Salda enterprise as inventory management system I chose to analyse the material components of the product group - Circular duct fans, because it is a standard product and the demand of this product is changing slightly. These products are used for air supply or extract in ventilation and air conditioning systems. Fans are mounted into a system of round air ducts and can be installed in any position; moreover fans can be mounted on the walls. These fans are not suitable for polluted air, aggressive and explosive gases.

Monthly demand is 1 569 products. According to the cycle times of the operations and lead time was found out that the min of Kanban batch has to be 80 components in the bin/container, and the max – 320 components, because it could be used two-bin Kanban system.

The main components which are included to make this product are: bracket, motor, cases, electrical box, capacitor and other small parts (screws, cables, holders and etc.) after analyzing the material of the main components I found out that all the time in the stock there are 450 components to make these products (or even more). According to maximum demand which is needed to be for the Kanban is 320 components. As a result the stock of inventory could be reduced by Kanban system **28.8 %.** A Kanban pull system could be used to pull the work through the system to fill the actual demand.

Moreover, with a help of the Kanban system it will be visual help to know when and which material enterprise has to order, as a result company will save the money by not ordering unnecessary material. Also, the components should be tagged that operators would move it to its designed area, which is nothing more than a place dedicated to specific components that are ready for other operation. This could help to solve existing quality problems, because the operators.

3.4.3. Problems of Implementing Kanban system

Kanban system implementation process is not easy and it takes time to implement it in the plant before it will start to function. However, Kanban can not be implemented in all chosen industry enterprises. After deep analysis of the empirical researches the criteria have been set for the enterprises, in order to know if the Kanban system could be implemented in their plants. We should understand that there are also failures associated with the introduction of Kanban.

After analysis of the different articles about the Kanban system implementation process and spending some time in couple companies which have implemented Kanban system we can main problems why this system does no work as it has to, because of general thinking when a kanban system is introduced to a production site.

Management. Very often a reason for failing to implement Kanban system has been a lack of knowledge and some common misunderstandings. Kanban systems are not complete within themselves and are not just systems were information is exchanged by cards. It is much more and depends on a powerful framework like a production system, committed employees willing to change and continuous improvement activities.

Management thinking must change. Kanban is not a method that can be implemented from top to bottom. Every Kanban cycle is improved by the employees of the processes themselves. It is not the task of the management to plan every detail and implement Kanban. The assumption and seeds should be provided by the management, but employees have the task to improve their Kanban cycle. According to the fact that Kanban requires a pull system and several other assumptions change of mindset of the operator is necessary. This cannot be done in several 1 hour presentations. Understanding of Kanban is easy, but realization is difficult. Japanese employees say that Kanban has to be "lived". This is the most important task of the management when Kanban is implemented. *"Ignoring the human aspects of Kanban systems operation will doom your implementation to failure!"*(SM Thacker & Associates, 2010).

Running Kanban. For running the Kanban in the organization everybody has to understand how it works and what they can or can not do. It includes everybody who runs the system: producer, "Kanban coordinator", "consumer". Everybody has to understand that control is driven by consumption, i.e. you can only produce the quantities pulled out of the system.

Producer must not supply defective products (risk of the customer downtime), can not produce anything without a Kanban card and can not produce too much, this will result undefined inventory, capacity, bottlenecks.

The "Kanban coordinator" is expected to homogenize the capacity utilization of the individual production areas, minimize the circulating Kanban cards (inventory optimization).

The “consumer” must not request more material than required (the limit is the total number of circulating cards = maximum inventory); must not request material prematurely (circulating Kanban cards without any actual demand).

Bad points. Should be avoided before the implementation of a Kanban system:

- High mix, many slow movers/variants.
- High variability presents (machine breakdowns, quality problems, absenteeism, engineering change, unreliable suppliers, etc.)
- Specialist resources/skills needed.
- No effective Master Production Schedule (MPS).
- Cyclic or seasonal demand (unless smoothed by MPS).
- Where team-working has not been introduced and individual payment incentives are removed.

It is the task of the management to improve the framework for the successful implementation of Kanban. The operator is responsible for its improvements. We have to make sure that all conditions are met in terms of production technology, organization and staffing.

Moreover it is some selection criteria for the enterprises:

- Equal, constain order calls (~ ±20 %) – (see selection matrix table 15); in order
- High degree of production safety (for plants, suppliers);
- Moderate set-up times (set-up time/production time <10 %);
- Qualified workers.

Table 15 Selection matrix

		Value of the parts		
		High	Medium	Low
Number of term of the parts	Regular	X	X	
	Changing slightly	X	X	
	Sporadic demand			

The selection matrix shows that the best option to implement kanban system would be for enterprises that have high or medium volume of the parts which does not change regular or changes just slightly. Kanban requires stability – even in seasonal business as long as forecasts are stable.

In order to improve the situation in the enterprise where Kanban system could be used, first it is necessary to reduce the volatility of the output, because it complicates the manufacturing process. These variations can be smoothed by elaborating out the adjustment of production schedules and justifying the quantities of the produced produce products detail quantities.

4. KANBAN SYSTEM IMPLEMENTATION IN INDUSTRIAL ENTERPRISES

After analysing all the research which has been done the Kanban System Implementation model has been set, which could be useful for the enterprises as a help while implementing this system, see fig. 30. The suggested Kanban system implementation model has main phases, which consist of different steps. By implementing Kanban System the inventory management system would be improved, as a result production costs would reduce too.

Proposed Kanban System Implementation model has three main stages which are composed of separate very important steps.

4.1. First stage: Planning and Preparation

Steps which has to be done:

1. *Become familiar with Kanban.* To know what Kanban is, to become familiar with it and to understand the options it offers.
2. *Collect data.* It will help to make decisions based on the facts. It includes: gathering data on sales demands over past years, changeover times, downtime, scrap levels, lead time, operation time, etc.
3. *Analysis of Data.* We have to know the demand pattern/average demand, times.
4. *Value Stream Map.* All collected data has to be used to form value stream map. It is very important to know the existing situation in the company, which is very important to know where non-value added processes are to improve it. Current state analysis which shows the existing process route, material flows, chart the existing process. With a help of value stream map will be possible to select the components of Kanban that will work in the facility. To identify right components for the Kanban system is very important.
5. *Set goals for the Kanban.* Kanban has to achieve goals which will explain why this system has been used.
6. *Calculate the Kanban size.* To calculate the Kanban container size based on current conditions. For the calculation is necessary to know changeover times, replenishment interval, productivity rate, planed downtime (data analyzed before it).

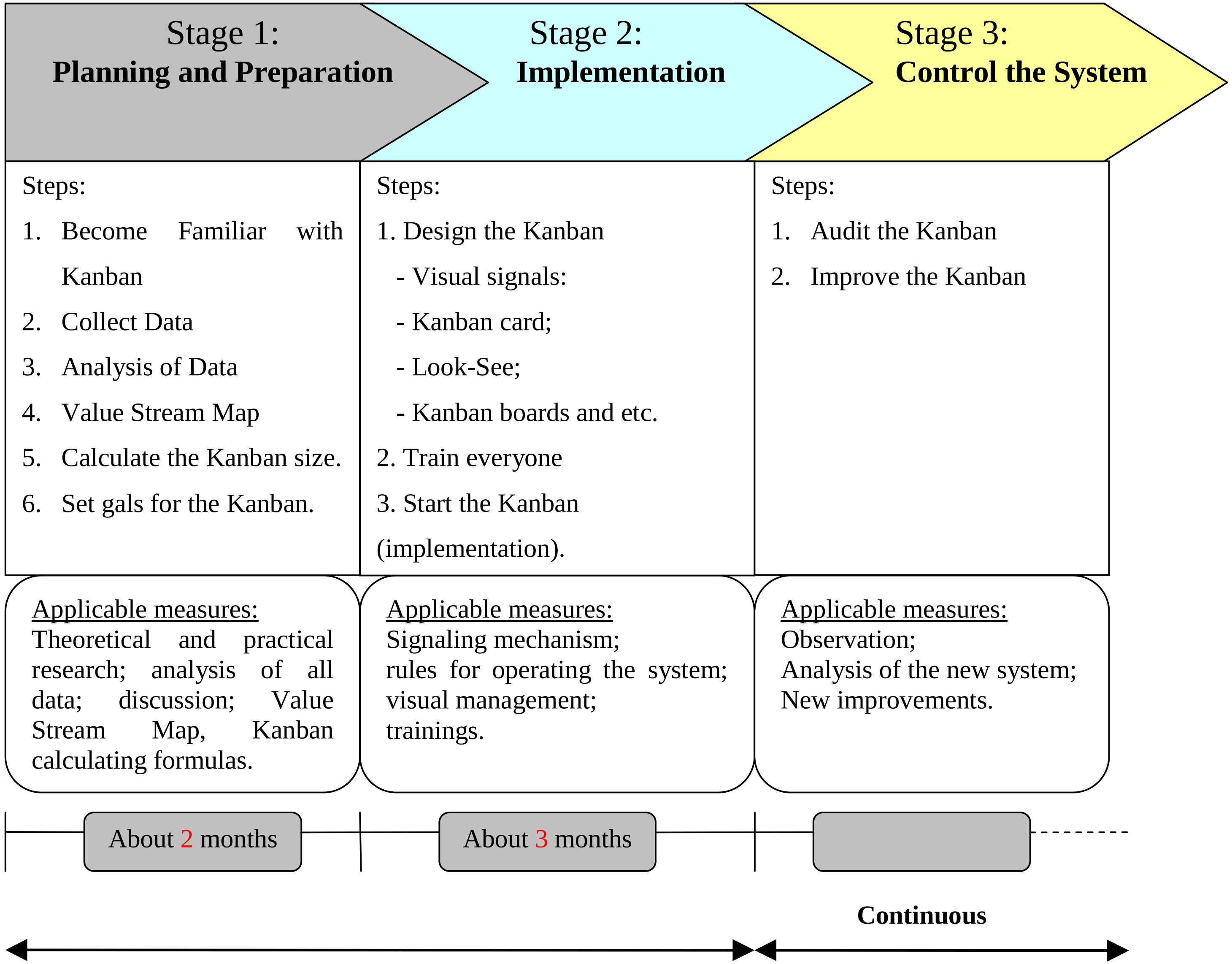


Fig. 30 Kanban System Implementation Model

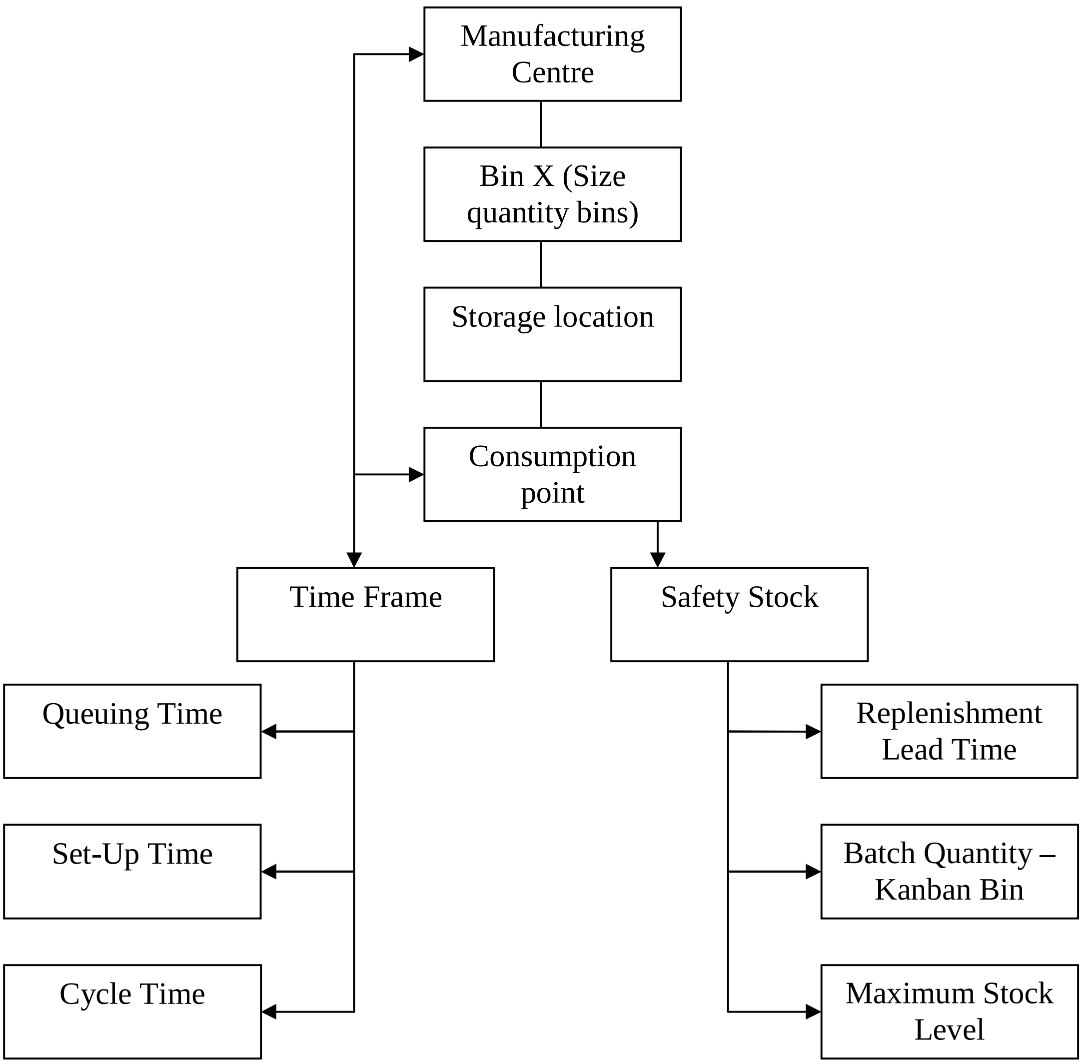


Fig. 31 Information Flowchart

Information which is needed for calculating and evaluating Kanban size is shown in Fig. 31 This flowchart shows the main criterions in which we have to pay attention in order to get a right size of the Kanban. Everything starts from determine which manufacturing centre is producing the parts/products that it is necessary to calculate the size of it. Also the Bin X which means how many bins it is necessary to have and the quantity of products/parts in the bin. Then we have to set the storage location. As a result of the information is standing consumption point which includes information about the time frame and safety stock. Between manufacturing centre and consumption point all the time is circulating the demand cycle, which influences the time frame.

The time frame information consists of: queuing time, set-up time, manufacturing cycle time. *Queuing time* is the time between the arrival of material at a workstation and the start of work on it.

Set-Up time it is a period required to prepare a device, machine, process, or system for it to be ready to function or accept a job. It is a subset of cycle time. [26]

Cycle time it is the period which requires to complete one cycle of an operation; cycle time is used on differentiating total duration of a process from its run time. [27]

Safety stock includes: replenishment lead time, batch quantity, maximum stock level.

Replenishment lead time ……

Batch quantity is the quantity of the parts/products should be produces after an evaluation of an inventory analysis.

Maximum stock level is the maximum stock level is that quantity of material above which the stock of any item should not normally be allowed to go. [28]

In order to improve Kanban size all these criteria which have been listed has to be improved first.

This first phase of the implementation process is the most important, because it is preparation and during this time all important information has to be gathered and must be carried out as detailed as possible.

4.2. Second stage: Implementation

Steps to be done:

1. *Design the Kanban.* After the calculations of the quantities needed to support the production requirement can design the Kanban. In order to create the design it is necessary to select the signalling mechanism, to develop the rules for operation of the Kanban and create a visual management plan.

   It is very important to think and design understandable Kanban visual signals. There are numerous ways to set up it. It can be common type's signals or specific ones that no one else has ever done. There are no rules for the visual signals; the main goal is for it that these signals have to work for your organization.

   Examples of some of the most common types of visual signals:

   - *Kanban card*, which has to identify important information about the component or product. It can be simple card or a label attached to a bin or container and the bin/container represents the Kanban. Kanban has to show import information system which can include such information us: the material number – to identify the part or product, optional the description of the part or a picture; the supplier (or source) of the part or product; the customer of the part or product; quantity per Kanban; the storage location; the way of transportation and etc.

   - *Look-See* uses floor marking or signals that tell when to replenish an item. It can be containers which shows necessity of the products when they are empty giving a signal to fill it up or used by colours: yellow, red. Yellow means it is time to replenish and red means you are in the danger zone.

- *Kanban boards* are variation of Kanban cards. The board simply uses magnet, plastic, chips, etc. Each object represents a container or production item. It works like the Kanban cards.

2. *Training.* To educate the employees involved in the Kanban processes. Everybody has to know how the system will work and they have to know exactly what their role is. This is very important stage, employees have to understand the main purpose of the Kanban and how it has to work, without understanding and intention from employees this system won't work, because Kanbans are different from the way most people are used to working, everyone using Kanbans must understand the rules otherwise they are very likely to undermine the Kanbans. A well-designed and implemented employee' training program helps employees to understand and implement Kanban system better**.** This stage is one of the milestones in the process.
3. *Start the Kanban.* When everybody is trained, all visual management pieces have to be in the places, the signals have to be set up, control points marked, and the rules completed.

4.3. Third stage: Control the system

Steps to be done:

1. ***Audit the Kanban.*** After the Kanban starts it has to be monitored and audited all the time. A person or team has to do it. When auditor discovers a problem corrective action needs to be taken immediately.
2. ***Improve the Kanban.*** After implementing Kanban system in the organization we have to look for a ways to improve it. The main purpose is to reduce inventory quantities.

   Kanban is to start with a generous number of Kanbans – containers, pallets, boxes, etc. Then systematically reduce the number of containers until the point at which the supply of materials is just in balance with the rate of use is reached. As containers are removed from the process, it will eventually reach the point at which production is delayed because the next container has not arrived yet. At this point add one container to the system to bring it back into balance. Moreover, process can be improved by reducing existing scrap value, downtime and changeovers.

To start the implementing Kanban, some elements and stages for successful implementation have to be considered. Each stage is very important and all of them have to be done. Improvements are always necessary. Kanban is not like playing cards. It is not enough to understand the Kanban philosophy – Kanban has to be "lived**".**

5. CONCLUSIONS

I. After making analysis of scientific methodical literature of the topic – Kanban system implementation in industrial enterprises was analyzed the main principles of it.

1. Analysis of the industry definition and Kanban concept was done by analyzing the literature of other authors, as a result I found that this system can help to solve few problems in the enterprises. The main problem that this system can help to solve out – inefficient inventory managing system in industries.
2. Moreover, the analysis of Kanban classification has been done. The main Kanban types are: Withdrawal Kanban (transportation) and production Kanban. These two main types are classified in more detailed sub-types: supplier Kanban and in-factory Kanban; production Kanban and signal Kanban. These Kanbans are used in different way, according to the situation in the plant.
3. Also, the basic operation of a Kanban control has been analysed, which demonstrated how dues-card system of the Kanban is working in order to understand how this system works and how it has to be controlled.
4. Nowadays industry has a very wide range of expressions. It can be seen as an economic sector which is dominated by production and includes large amount of capital or it can be seen as a grouping of business activities in accordance with certain features.

II. After making analysis of industry classification and specific features of it I found out that:

1. There are many different kinds of industries, and often organized into different classes or sectors by a variety of industrial classifications. Industry is classified by: economic activities, production types, organizational form of production and size. According to these specifications I chose to analyze the Kanban Implementation process which will be apply for non-domestic cooling and ventilation equipment production industry.
2. Each industry has the specific lineaments and requirements of the products which it is producing or services are providing. The industry which I am analyzing has specific standards such as: ISO 91.140.30; EN779:2002; ISO 16813:2006; ISO 900.

III. The analysis of theoretical models of Kanban system implementation into industrial enterprises has been analyzed. This analysis has been made according to the suggested models of other authors in order to know what could be improved in it. After analyzing mentioned models for the implementation process I can maintain that the best classification would be which Mukhopadyay S.K. and Shanker S' (2005) is suggesting, because after overall methodology they divided the process into big phases and smaller particulars, it facilitates the understanding about the main process.

IV. The empirical research in the selected industrial enterprises of the Kanban system has been made.

5. Firstly, it was important to analyze and to know the current situation in the selected Lithuanian industry, which is non-domestic cooling and ventilation equipment manufacture, in order to know its tendencies. All the data was taken from Lithuanian Development Agency and Lithuanian Department of Statistic hence they are competent. It was found that the best situation (comparing from 2006 to 2009 year) was in 2008.

   It was found that comparing 2006 and 2009, incomes are bigger by 3.32 per cent. Even if during 2009 this industry decreased, according to the data about 1st quarter of 2010 when incomes are bigger by 45 per cent comparing with 2009 1st Qtr, we can presume that this industry is starting to rice again. Moreover, it was found that the selected sector takes 2.42 per cent from all of the manufacturing industry.
6. In the successive part of the empirical research, the brief interview about the use of the Kanban system was made for the additional sector – manufacture of structural metal products, in order to compare the prevalence of this system in two different but in the same time similar sectors.
7. The written questionnaire was prepared on the basic of analysed theory on Kanban system Implementation process. The questionnaire was subsequently sent by email to the enterprises. The questionnaire used in the study contained different types of question. One kind of questions was concentrated on general information bout the company; the other type of questions was concentrated on the actual industrial enterprises problem. Using Sample Size calculator it was evaluated confidence interval: *c=10.28.* Sample size = 27 enterprises.
8. Regarding e-mail, telephone interview and survey results, I observe that most of the respondents do not use and have not heard anything about the Kanban (50 per cent), less then half of the respondents (31.8 per cent) have heard about this system and just the smallest part is using this system (18.20 per cent).
9. Survey results shows (according to the analysis which was made with a help of SPSS program, by setting Kruskal-Wallis and Mann-Whitney criteria's) that be biggest problem in enterprises – material management problems, after it goes additional production costs, then inventory management problems, next information supply problems, storage problems, quality problems, and the some additional problems as: low attention to details and lack of trained workers.
10. In order to determine the relation between the production problems and enterprise specification it was decided to make correlation. In order to look for more details to the causality, the

correlation was measured by Spearman's coefficient. I observe that differences were statistically significant between storage problems and information supply problems. Moreover, the regression and correlation analysis was made to evaluate a relationship between Kanban system and its criterions. The connection between the criterions such as: employee satisfaction of this system depends of visualization management system; the effectiveness depends of easiness to understand the system and the scheduling system depends of its necessity. The connection between all these variations according to the correlation coefficient is very strong.

11. Analysis of the implementation process was made in TROX UK Ltd as this company has implemented this system. This system reduced the production lead time in the company from 11 days to 5.5 days (by 50 per cent). Moreover, the inventory management system now is more stable then it was before. Explained, is the details of each implementation process step in this company, what problems were encountered and how it was solved.
12. The analysis of the current situation in the enterprise UAB Salda has been done, having in mind if Kanban system should be implemented in it. After the analysis I can maintain that by implementing Kanban system the inventory level in this enterprise would reduce by 28.8 per cent.

V. After the analysis of the theoretical and empirical aspects a model of the Kanban system implementation process for the industrial enterprises, which would help to understand and install this system faster and to avoid main problems which can occur by implementing this system in the plant has been proposed.

This model is different from others because it is easy to understand what stages and steps should be done, all explanations is given how to make each step and what not to for get. If all the routines will be tracked consistently like it is shown in the model and adhering to all rules the implementation process will be shorter according to other authors suggested models.

Suggestions:

1. During the research and according to all the analysis which was made. By collecting the data, the priority of the problems was investigated. I observe that the Kanban system is bringing great opportunities to solve the existing problems; therefore one of the options would be to install this system. By implementing Kanban system the management of inventory would improve and would alleviate other related problems such as long lead time, etc.

2. Before implementing this system into the enterprises it has to be fully acquainted with a purposed model in order to achieve good results. The employees in the enterprise must be also informed as much as possible about this system in advance.
3. From the survey, I observe, that one of the repellent facts is that the duration of the implementation is long. My proposal for this problem would be to create a team of 2-3 people, consisting of production and design staff (different speciality people have to be involved). This team could take care about: Kanban System Implementation and other Improvements in the enterprise, in order to achieve quicker results.

REFERENCES

1. Arora N.R. 2009. Kanban: Kanban guide. *Demand Scheduling for Lean Manufacturing*. World Class Building Lean, Fit, Competitive Organizations. Graphic Products, inc.
2. Bicheno, J. 2004The New Lean Toolbox: Towards fast, Flexible flow. England.
3. Classification of economic activities, [cited 2010.01.02] Available from internet: http://www.stat.gov.lt/doc/10103591/Kanban
4. Regression and correlation analysis, [cited 2011.05.22] Available from internet: http://abyss.uoregon.edu/~js/glossary/correlation.html
5. Wikipedia, [cited 2011.05.22] Available from internet: http://em.wikipedia.org/wiki/Chi-square_test
6. Wikipedia, [cited 2011.05.22] Available from internet: http://en.wikipedia.org/wiki/P-value
7. Wikipedia, [cited 2010.08.10] Available from internet: http://hubpages.com/hub/Kanban-Calculation
8. Kaizen institute, [cited 2011.04.24] Available from internet: http://uk.kaizen.com/completencies/kaizen-tools/kanban.html
9. Maximum limit/level, [cited 2011.05.17] Available from internet: http://www.accountingformanagement.com/maximum_limit_or_maximum_level.htm
10. Business dictionary [cited 2011.05.17] Available from internet: http://www.businessdictionary.com/definition/cycle-time.html
11. Business dictionary, [cited 2011.05.17] Available from internet: http://www.businessdictionary.com/definition/setup-time.html
12. http://www.esru.strath.ac.uk/EandE/Web_sites/05-06/constr_village/new_page_7.htm [cited 2011.05.18]
13. Institute for Manufacturing, [cited 2009.10.09] Available in internet: http://www.ifm.eng.cam.ac.uk/dstools/process/kanban.html
14. International Organization for Standardization, [cited 2011.05.18] Available from internet: http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_ics_browse.htm?ICS1=91&ICS2=140&ICS3=30
15. Reading/searching site, [cited 2011.04.24] Available from internet: http://www.scribd.com/doc/10103591/Kanban
16. Statistics Lithuania, [cited 2010.01.02] Available from internet: http://www.stat.gov.lt/uploads/klasifik/EVRK/EVRK.htm
17. James P. Womack, Daniel T. Jones. Lean thinking: Banish waste and create wealth in your corporation. 2003, p. 379.

18. Jeffrey K. Liker. The Toyota Way. 14 Management Principles from the World's greatest Manufacturer, 2004, p. 319.
19. Kaizen Institute, [cited 2010.04.24] Available from internet: http://uk,kaizen.com/completencies/kaizen-tools/kanban.html
20. Kanban Signaling: Two Pillars of TPS
21. Lithuanian Department of Statistic, [cited 2010.11.13] Available from internet: www.stat.gov.lt
22. Lithuanian development Agency, [cited 2010.11.12] Available from internet: www.lda.lt
23. Lithuanian Republic law of small and medium-sized business, [cited 2010.01.02] Available from internet: http://www3.lrs.lt/pls/inter2/dokpaieska.showdoc_l?p_id=238716
24. Markey M. 2005. Industrial Management. *Examining a Kanban Material Acquisition System.* Institute of Industrial Engineers, Inc. (IIE), 22.
25. Masaaki Imai. Gemba Kaizen: A Commonsense, Low-Cost approach to management. 1997, p. 343.
26. Mertins K.; Lewandrowski U. 1999. Inventory safety stocks of Kanban control systems. *Production Planning & Control: The Management of Operations.* Volume 10, Issue 6. 520-529.
27. Mokšin, V., Striška, V. Įmonių projektavimas: mokomoji knyga. Vilnius: Technika, 2006. 262
28. NACE Rev.2 Statistical classification of economic activities in the European Community. Eurostat methodologies and working papers. 2008, p.363. ISSN 1977-0375.
29. Phil Robinson. Business Excellence. The Integrated Solution to Planning and Control, 2006, p. 241.
30. Shingeo Shingo. A study of the Toyota Production System from and Industrial Engineering Viewpoint. Productivity Press: 1986, p.257.
31. Survey Software, [cited 2011.01.20] Available from internet: http://www.surveysystem.com/sscalc.htm
32. Suzaki K. The New Manufacturing Challenge. 1987, p. 255.
33. Tapping D.;Luyster T.; Shuker T. *Value Stream Management. Eight Steps to Planning, Mapping and Sustaining Lean Improvements.* Production Press: New York, 2002, p.176. ISBN: 1-56327-245-8
34. The productivity press development team. Kanban for the shopfloor.
35. University of Cambridge; Institute of manufacturing
36. Wikipedia, [cited 2009.12.06] Available from internet: http://en.wikipedia.org/wiki/Industry
37. Wikipedia, [cited 2010.12.02] Available from internet: http://en.wikipedia.org/wiki/Statistical_sample
38. Wikipedia, [cited 2009.12.06] Available from internet: http://en.wikipedia.org/wiki/Kruskal%E2%80%93Wallis_one-way_analysis_of_variance

39. Wikipedia, [cited 2009.12.06] Available from internet: http://en.wikipedia.org/wiki/Mann%E2%80%93Whitney_U
40. Wikipedia, [cited 2010.12.20] Available from internet: http://en.wikipedia.org/wiki/Sample_size
41. Consultancy "Strategos", [cited 2009.10.09] Available from internet: http://www.strategosinc.com/kanban.htm
42. Introduction to Kanban article by: Steve Hudgik
43. Free online productivity and safety tutorials, [cited 2009.10.08] Available from internet: http://www.graphicproducts.com/tutorials/kanban/index.php
44. Mukhopadhyay S.K., Shanker S. Kanban implementation at a tyre manufacturing plant: a case study. *Production Planning & Control*, Vol. 16, No. 5, July 2005, 488-499.
45. Consultancy "Lean Sigma Supply Chain", [cited 2010.06.16] Available from internet: http://www.resourcesystemsconsulting.com/blog/archives/1141

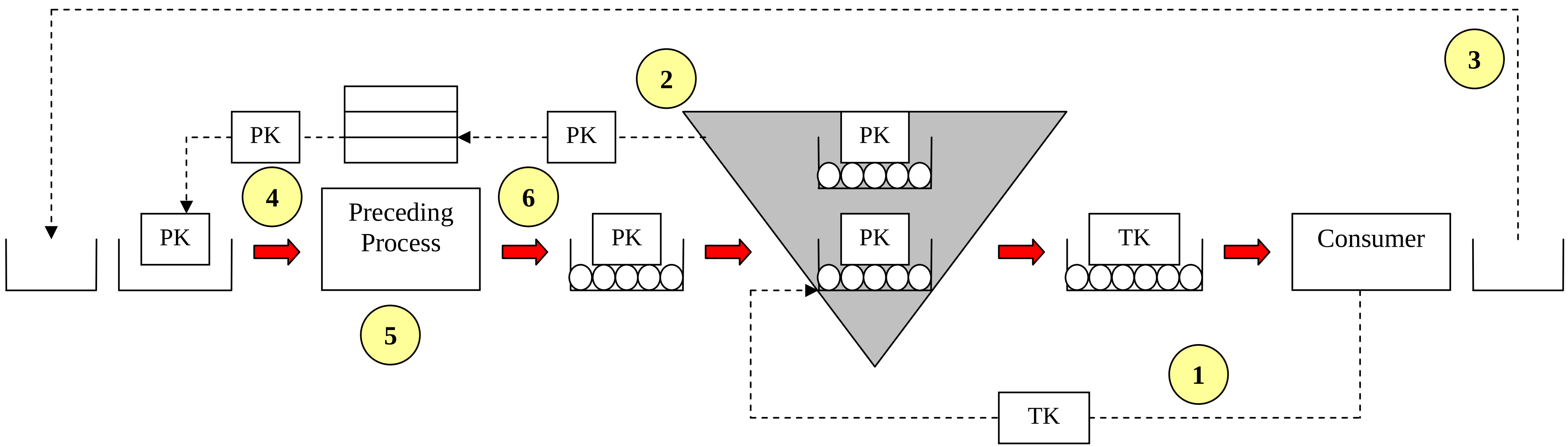
APPENDIXES

Cclassification Economic Activities in the European Community [25]

NACE Rev. 2	
Section	Description
A	Agriculture, forestry and fishing
B	Mining and quarrying
C	Manufacturing
D	Electricity, gas, steam and air conditioning supply
E	Water supply, sewerage, waste management and remediation activities
F	Construction
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
I	Accommodation and food service activities
H	Transportation and storage
J	Information and communication
K	Financial and insurance activities
L	Real estate activities
M	Professional, scientific and technical activities
N	Administrative and support service activities
O	Public administration and defence; compulsory social security
P	Education
Q	Human health and social work activities
R	Arts, entertainment and recreation
S	Other service activities
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
U	Activities of extraterritorial organisations and bodies

APPENDIX 2

Kanban Control



X Steps

Kanban-Box

Store

Production Area

Flow of Material

Flow of Information

PK Production Kanban

TK Transport-Kanban

Transport container

Anketa apie "Kanban" sistemos naudojimą pramonės įmonėse

Anketos duomenys bus naudojami Kanban sistemos naudojimo analizei atlikti bei baigiamajam magistro darbui parengti.

Darbo tema: "Kanban" sistemos taikymas pramonės įmonėse

1. Jūsų įmonės pagrindinė veikla? ....

2. Kiek Jūsų įmonėje dirba darbuotojų?

○ 1 – 10 ○ 11 – 50 ○ 51 – 250 ○ 250 – 300 ○ daugiau nei 300 darbuotojų

3. Didžiausia įmonės produkcijos dalis yra:

○ standartiniai gaminiai ○ nestandartiniai gaminiai ○ mišri gamyba

4. Jūsų nuomone, kokios yra problemos su kuriomis dažniausiai susiduria įmonė?

	Nesusiduria	Retai	Dažnai	Pastoviai
▪ Atsargų valdymo sistema	☐	☐	☐	☐
▪ Sandėliavimo valdymo sistema	☐	☐	☐	☐
▪ Papildomos gamybos išlaidos	☐	☐	☐	☐
▪ Medžiagų valdymo sistema	☐	☐	☐	☐
▪ Informacijos tiekimo valdymo problemos	☐	☐	☐	☐
▪ Kokybės problemos	☐	☐	☐	☐
▪ Kita (įrašykite)...	☐	☐	☐	☐
▪ Kita (įrašykite)...	☐	☐	☐	☐
▪ Kita (įrašykite)...	☐	☐	☐	☐

5. Ar esate susipažinęs(usi) su Kanban gamybos valdymo sistema?

○ taip ○ ne ○ esu girdėjęs(usi)

6. Ar Jūsų įmonėje yra įdiegta ši gamybos valdymo sistema? (jei atsakymą parinkote NE toliau pildyti anketos nereikia)

○ taip ○ ne ○ šiuo metu yra diegiama

7. Jūsų manymu, kokie yra Kanban sistemos privalumai?

☐ Optimizuoja inventorizaciją ir sumažina produktų senėjimą

☐ Suteikia lankstumo gamybai

☐ Sumažina visas išlaidas

☐ Pagerina gamybos srautą

☐ Sumažina atliekų kiekį

☐ Padidėja gamybos apimtis

☐ Geresnis mašinų panaudojimas

☐ Kita(įrašykite) ....

8. Jūsų manymu, kokie yra Kanban sistemos trūkumai?

□ Sunkiai suprantama sistema □ Neefektyvi sistema

□ Brangi sistema □ Lėtai reaguoja į paklausos pokyčius

□ Kita (įrašykite) ....

9. Kokios pagrindinės kliūtys atsirado diegiant šią sistemą? (įrašykite)

....
....

10. Kiek laiko užtruko šios sitemos diegimas?

○ 1 – 3 mėn ○ 3 – 6 mėn ○ 6 – 9 mėn ○ 9 – 12 mėn ○ daugiau nei 12 mėn

11. Jūsų manymu, kas pasikeitė įmonėje įdiegus šią sistemą? (įrašykite)

....

....

APPENDIX 4

The questionnaire about the "Kanban" system usage in TROK UK Ltd enterprise

Data of the questionnaire will be used for the analysis of the Kanban system and for the preparation of the final master thesis.

Thesis: Kanban system implementation in industrial enterprises

1. What is your work position in the company?

…………………………………………..................................

2. Is your work experience in the company?

○ less than 1 year ○ 1 – 3 years ○ 3 – 5 years ○ more than 5 years

3. In your opinion, what are the problems that company faces in most cases?

	Do not have	Rarely	Often	Permanently
▪ Inventory management problems	☐	☐	☐	☐
▪ Storage problems	☐	☐	☐	☐
▪ Additional production costs	☐	☐	☐	☐
▪ Material management problems	☐	☐	☐	☐
▪ Information supply problems	☐	☐	☐	☐
▪ Quality problems	☐	☐	☐	☐
▪ Other (write)...	☐	☐	☐	☐
▪ Other (write)...	☐	☐	☐	☐
▪ Other (write)...	☐	☐	☐	☐

4. Are you familiar with Kanban production control system?

○ yes ○ no ○ a little bit

5. Evaluation of the Kanban system:

Categories	**Ratings**				
	poor (1)	below average (2)	average (3)	above average (4)	excellent (5)
1. Employee satisfaction of this system					
2. Visual management system					
3. Scheduling system					
4. Necessity					
5. Effectiveness					
6. Easy to understand					

Kanban system implementation process in Trox UK Ltd.

No	Steps	Period of time	Problems	Reason	Additional time
1.	Gather data on sales demand over the last two years.	1 week	Obstacles to obtain statistical data.	Lack of information between the departments.	1 week
2.	Analyse the data – demand pattern/average demand.	2 weeks			
3.	Establish the existing process route & material flows.	2 weeks.			
4.	Chart the existing process – current state analysis.	2 weeks			
5.	Establish if the Baan BOM Structure supports Kanban.	3 weeks	Baan system (system which helps to plan and organize the production in the enterprise	Not enough people who know by detail how this system is working (2 people).	1 week
6.	Examine options for changing the structure to support Kanban.	2 weeks			
7.	Establish desired transfer batch size and specify pallet size.	2 weeks			
8.	Produce factory layout defining Kanban locations; quantity & positions.	2 weeks			
9.	Design and order suitable containers.	3 weeks	Bad design of the bins; supplier delays	In the design process quality department was not included; supplier run out of the material.	4 weeks
10.	Mark floor with locations & bins with part data.	2 weeks			
11.	Draw up an SOP for Kanban process, shown in appendix 5.	1 weeks			
12.	Educate those involved in the re-supply rules.	1 week	A pessimistic approach to a new system.	Employees used to work in the old order and did saw any need to change it.	1 week
13.	Run system & monitor.		Problems with controlling the system.	“Producers”, “Kanban coordinators”, “consumers” misunderstandings.	

Kanban size calculation for the AFG material parts

Kanbine size = average usage x replenishment time (days)

Daily average	8
Replenishment time	5
Kanban size	**40**

Finished AFG

Daily Demand	8	Demand during lead time	40
Production Lead Time	5	Safety stock level	40
Safety Stock	1	Maximum inventory level	80
Kanban Size	**40**	**Number of kanbans needed**	**2**

Quantity of the parts

Parts	**Quantity**	Run time [min]	Hours	2 bins [h]
AFG Grille	**160**	180,8	3,0	6,0
AFG Border	**160**	310,8	5,2	10,4
Shiffeners	**200**	86	1,4	2,9

APPENDIX 7

Standard Operating Procedure for the Kanban System (SOP)

Standard Operating Procedure

Title: Kanban ‘T’ card traffic light system.

1. When you are about to start using the reserve stock, the green area to the red area of the rack.

2. The ‘T’ cards are checked twice daily by the planning department & any items in the red will be noted, an order raised & the ‘T’ card moved in to the yellow column by the planning department to signify this.

3. Once the ordered items have arrived at the line, on your line leader’s instructions the reserve stock sealed in a bag should be the first to be replenished, the rest of the items placed in the working tray bin.

4. The ‘T’ card is then moved to the green column & all is well until the next time the reserve stock bag is torn open.