INTEGRATED DESIGN OF PRODUCTION SYSTEMS IN A LIGHTING MANUFACTURER – using CAD and Simulation in Layout and Process Optimization

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ABSTRACT

This paper discusses production systems design issues, applied to the production system layout of a manufacturer of lighting fittings and components. In this paper, production systems design software tools – Information Systems, Simulation and Computer Aided Design are integrated, exploring ways of dealing with data diversity and assuring valid and efficient production system layouts, taking advantage of the mentioned data integration. This integration is implemented on Microsoft Access (databases with system knowledge repository), AutoCAD (layout design) and WITNESS (simulation). The software package developed was called IDS (Integrated Design of Systems). This approach can help on global system optimization that considers all important system resources and system performance measures. Solutions are expected to be faster to achieve and better than solutions obtained with non-integrated approaches. IDS approach is open and accessible, thus enabling different companies to use this advanced production systems design tool, taking advantage of simulation and CAD systems and their integration. This application intends to validate the concept and functionalities of the proposed tool, on a real industrial case study.

KEYWORDS: **SIM**ulation. Integrated Systems Design. Integrated Layout Design.

1 INTRODUCTION

1.1 Description of the Systems Design problem

Production System Planning and Design (PSPD) is a complex set of tasks using knowledge from several fields: scientific, logical, economical, management, statistical, technical and information technology.

It consists of planning and evaluating different alternatives of systems aiming the global optimal usage of inputs and all kinds of resources. Alternatives are designed regarding dynamic time changes and stochastic influences (Francis & White 1974), (Heragu 2006).

Nowadays, there is a great pressure on production systems design to be developed or reorganised rapidly and efficiently due to the worldwide competitive market and rapid progress in manufacturing processes. In this dynamic context, flexibility, modularity and robustness are desired production system properties. This paper deals with production systems design and its improvement. It is focused on the design of systems and layouts based on material flows, on re-layout processes and also on the design of layouts influenced by different types of uncertainties.

As far as Production Systems Design is concerned, three basic classes of software tools have been used: Computer Aided Design, Process Simulation and Information Systems. However, these software tools have been used with low levels of integration. The absence of data integration within these three classes of software tools, and also the absence of a systemic approach to Production Systems Design have been causing duplication of work, waste of time, incoherencies, difficulties in project team communication, and errors in the design phase.

Pandey et al. (2000) make an interesting contribution towards this type of tools integration, with a model that is optimised by simulation and adapting the results into layouts. Also, Altinkilinc (2004) improved systems with simulation and used a CRAFT method for layout optimization.

According to Grajo (1995), layout optimization and simulation are two tasks that are fundamental to facility planning. Burgess et al. (1993) proclaimed that simulation is the only methodology robust enough to the systematic examination of key variables of factory performance. Simulation methodology enables the representation of many attributes of real life problems that are difficult to consider in analytical models for the layout optimization (Tam & Li 1991)(Tang & Abdel 1996)(Pandey et al. 2000)(Castillo & Peters 2002).

1.2 Integrating Systems Design through a proposed tool (IDS)

In this paper the tools integration is implemented through Integrated Design of Systems (IDS) tool – see Figure 1, which uses Microsoft Access (database), AutoCAD (layout design) and WITNESS (simulation), and makes use of the issues discussed in Vik et al. (2010b)(2010c), concerning the production system design software tool developed and presented in the above papers. MS Access provides an open database structure, allowing integration and data exchange between WITNESS and AutoCAD. Simulation helps on dynamic systems analysis and CAD on static arrangement on a feasible implementation. Iteratively the results from the simulations are used to improve CAD layout design, and CAD layouts are used in new simulation experiments. This approach can help on global system optimization that considers all important system resources and system performance measures.

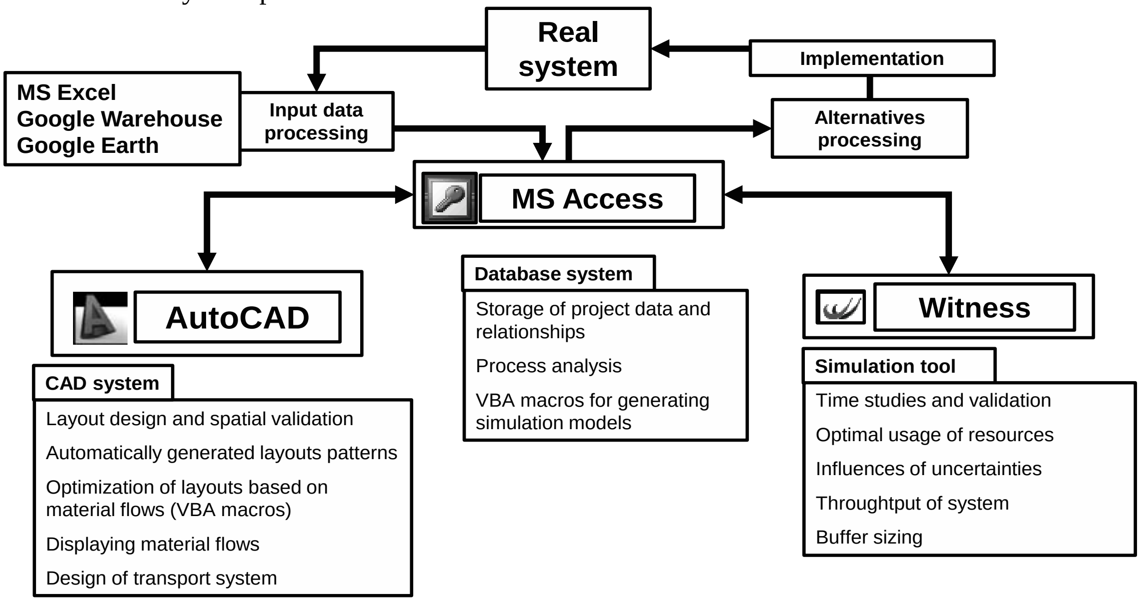

Figure 1 - IDS Overview

The main differences between the traditional (non-integrated) approach and IDS are shown in Figure 2. The traditional approach (left side) often uses tools separately or with minimum relative integration and data can be stored in several places and in different formats. On the other hand, IDS makes use of a full integration (right side of Figure 2). A similar idea of integration is described in other works (Chee, 2009)(Benjaafar & Sheikhzadeh, 2000)(Sly & Moorthy, 2001).

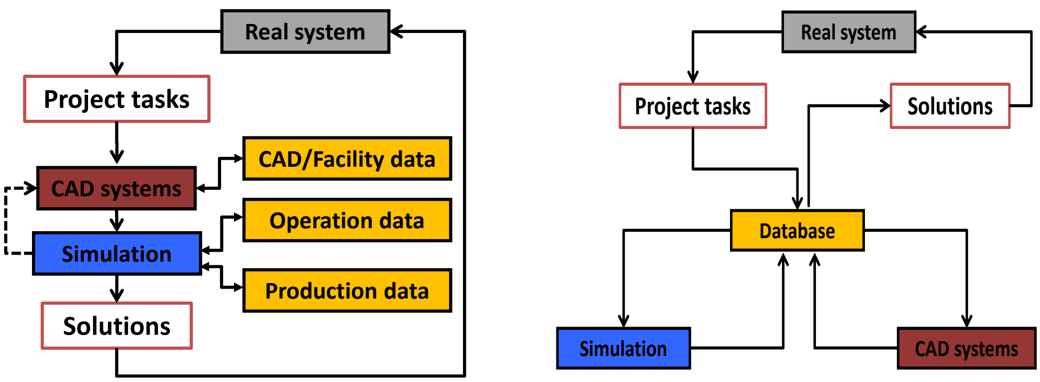

Figure 2 - Traditional Approach vs. proposed approach (IDS) for Production Systems Design

Taking into consideration the referred disadvantages of known (non-integrated) approaches to production systems design phase, the software tool should acknowledge a high automation level. In fact the proposed ***I**ntegrated **D**esign of **S**ystems* tool (*IDS*), involves a wide set of functions for the most common tasks of production systems design, from conceptual level to implementation level: systems analysis (P-Q, cluster and material flow analysis), automatic generation of simulation models, generation of facility and factory layouts alternatives, material flows displaying, transportation system design and iterative buffer size specification.

Integration is managed by one common database. It allows specifying and controlling simulation model from database and read/write the required/received data.

IDS shows several alternatives and provides detailed information on production systems performance measures, enabling to choose the best solution.

Solutions achieved using IDS are expected to be better than solutions obtained with non-integrated approaches.

IDS approach is open and accessible, thus enabling different companies to use this advanced production systems design tool, taking advantage of simulation and CAD systems and their integration.

2 Description of the case study

The Company is a Czech producer of lights for offices, factories, homes, etc., with a monthly production around 120’000 different types of lights (see Figure 3 - Modus products

) (www.modus.cz, 2011). The company belongs to the greatest light technique producer and exporter of the Czech Republic. The company resulted from the union of several small firms in 1994. It has grown and spread its market activity all over the world.

Figure 3 - Modus products

This project is focused on optimising the production system layout. The reasons are clear – the current layout organisation causes a large material manipulation, transportation and storing of parts that leads to extra costs as well as prolonging lead time. These factors are typical when re-layout is required.

This department is currently based on the process layout pattern, built in the beginning of the company. There was a more specific customer production and the job-shop layout was efficient. Nowadays, the production (product portfolio and volumes) have changed to more stable and the current layout pattern became ineffective due also to the placement of a new kind of production equipment just into free spaces in the factory, not into the optimal position.

Main tasks of this project are concerned in the re-layout activity and change current process layout into product or cellular layouts. In these layouts, production facilities are ordered based on operation sequences or similarities in the production.

This example is focused on metal-forming department facilities with similar technologies – Figure 4 (www.modus.cz, 2011). In this department, there are machines and production equipment that are used for:

- cutting raw material (saws, material feeders)
- eccentric presses (getting shapes)
- punching machines

- bending and roll-bending

The production equipment can be moved and then be involved in the re-layout. The following operations and equipment are not involved in this project: painting, mouldering plastic parts, warehouse and final assembling in the workstations (WS). These facilities have fixed position in this project and it is so for the following reasons: the assembly WSs are much closer to the warehouse activities and these two departments must be close. The assembly WSs is convenient in places far from metal-form departments due to the noise, vibrations, etc. Painting facilities consist of a complete line, where moving is very expensive. Mouldering machines need special equipment: a crane to change heavy moulds and also a supply of plastic material.

CNC bending machine

Bending line

CNC punching machine

CNC roll bending machine – LUNA (www.lunabendingrolls.com, 2011)

Paint shop

Assembly workstations

Figure 4 - Images from metal-forming and production areas

2.1 System Knowledge Database

All input data are received from the company's database. Input data are: a list of inventory and used technology, a list of products, production volumes, the current layout and the available space and a sequence of operations. This project involves thirty-four machines and thirty-three products. The light types “I”, “LLX”, “LLY”, “SB”, “LL” and “K” are assembled from sub-parts, based on the Bill of Material (BOM). The production volume is an average of the week throughput that is based on two years of the production schedule analysis.

These data are saved in DB and AutoCAD – Figure 5.

List of inventory and technology:

id	name_machine_sim_	process_technology
22	M_06	Excentric Presses
23	M_20	Rolling
24	M_21	Rolling
25	M_04/05_25	Excentric Presses
26	M_09	Metal forming
27	M_07/08_27	Metal forming
28	M_33	Metal forming
29	M_65	Hydraulic Table Shears
30	M_35	Hydraulic Table Shears

Production:

Part_name	Number_arrived
I_7	20391
LLY_11	1804
LL_23	1720
LL_22	172
LL_24	172
SB_16	1450
SB_17	1450
I_4	13594
I_6	13594
I_9	13594
LLX_36	11176
LLX_37	11176

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Production schedules:

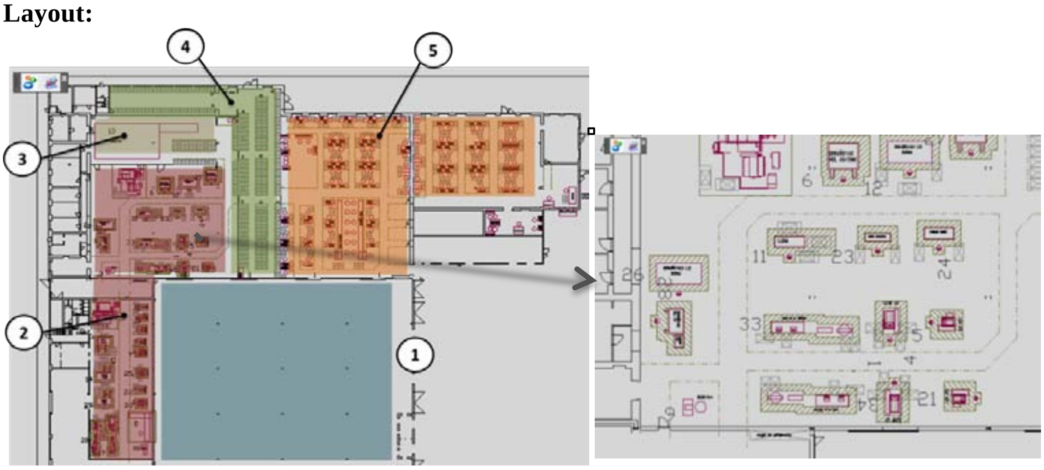
21.8.2006	SPMB113NMB170	Downlight MODUS SI
21.8.2006	SPMB126NMB170	Downlight MODUS SI
21.8.2006	I336ALDP600EP	MODUS I 3x36 W hli
21.8.2006	I318B600EP	MODUS I 3x18 W bíl
21.8.2006	I314ALDPA600NZ3	MODUS I 3x14 W hli
21.8.2006	I318AL600	MODUS I 3x18 W hli
21.8.2006	LLX236AL	MODUS LLX 2x36 W
21.8.2006	I336ALDP600	MODUS I 3x36 W hli
21.8.2006	I436ALDP600	MODUS I 4x36 W hli
21.8.2006	I436ALDP600EP	MODUS I 4x36 W hli
21.8.2006	I414ALDPA600VERZE1	MODUS I 4x14 W, hl
21.8.2006	I414ALDPA625VERZE1	MODUS I 4x14 W, hl
21.8.2006	I414ALDPBY625VERZE1	MODUS I 4x14 W, hl
21.8.2006	I414ALDPC600VERZE1	MODUS I 4x14 W, hl
21.8.2006	I414ALDPC600EPSDDVERZE1	MODUS I 4x14 W, hl
21.8.2006	I314ALDPA600VERZE1	MODUS I 3x14 W hli
21.8.2006	I314ALDPA600NZ3VERZE1	MODUS I 3x14 W hli
21.8.2006	I314ALDPA625VERZE1	MODUS I 3x14 W hli
21.8.2006	I314ALDPC600VERZE1	MODUS I 3x14 W, hl
21.8.2006	I314MATDPA625VERZE1	MODUS I 3x14 W ma

Operation sequences:

SubForm_Tbl_Simple_Production_lines

Machine nai	Part name	Order part
M_04/05_21	I_7	2
M_38	I_7	3
M_07/08_27	I_7	4
Assembly_WS	I_7	5
M_37	I_8	1
M_06	I_8	2
M_21	I_8	3
M_04/05_25	I_8	4
Assembly_WS	I_8	5
M_04/05_21	I_9	1
M_06	I_9	2
M_20	I_9	3
M_09	I_9	4
Assembly_WS	I_9	5
M_36	LLY_10	1
M_10	LLY_10	2
Assembly_WS	LLY_10	3
M_40	LLY_11	1
Assembly_WS	LLY_11	2
M_37	LLY_12	1

Layout:



1. **Storage of raw material**
2. **Metal-forming department**
3. **Paint shop**
4. **Warehouse**
5. **Assembly workstations**

Figure 5 - Input data analysis

3 IDS Approach

Based on the results of material flows values of the current situation (PQ analysis), it is clear that the most produced parts are the lights “I” and “LLX”. Lights “SB”, “LLY”, “LL” and “K” have very low production volumes (see Figure 6).

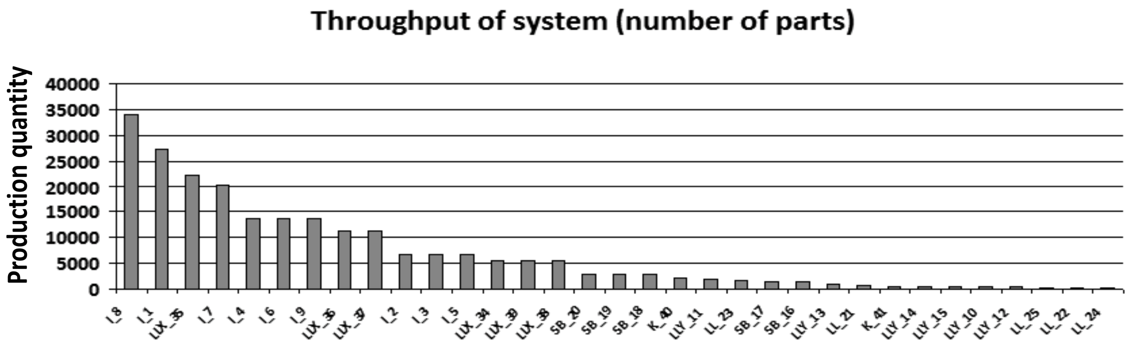


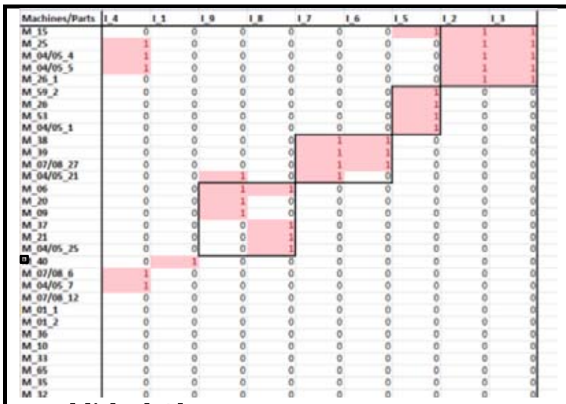
Figure 6 - PQ analysis

Machines for “I” parts must be as close as possible to achieve minimum material flows. For the optimization of material flows, the following approaches can be used:

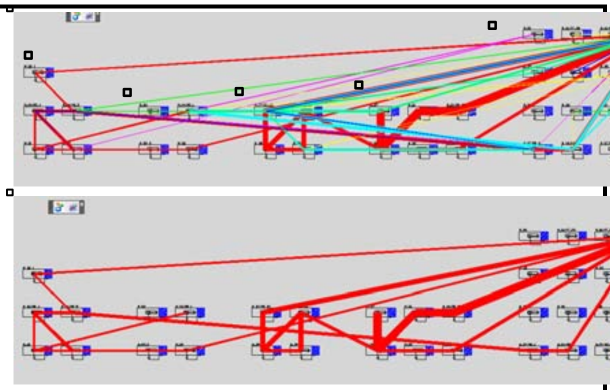
- layout based on clusters (Alternative “Cluster”)
- layout based on production lines (Alternative “Production line”)

3.1 Alternative a)“CLUSTER”

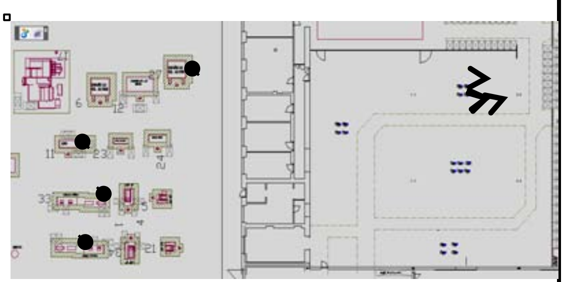
For parts “I” and “LLX” a cluster analysis is performed – see Figure 7.



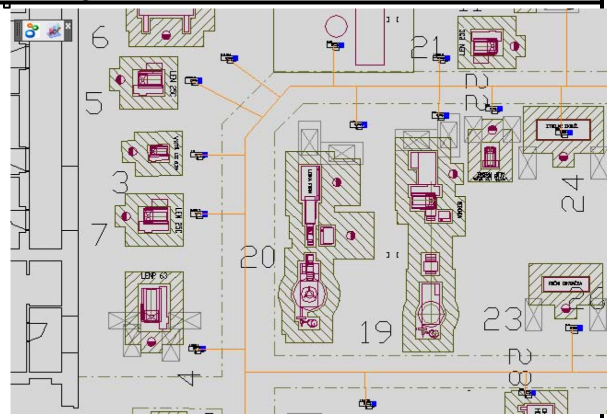
Established Clusters



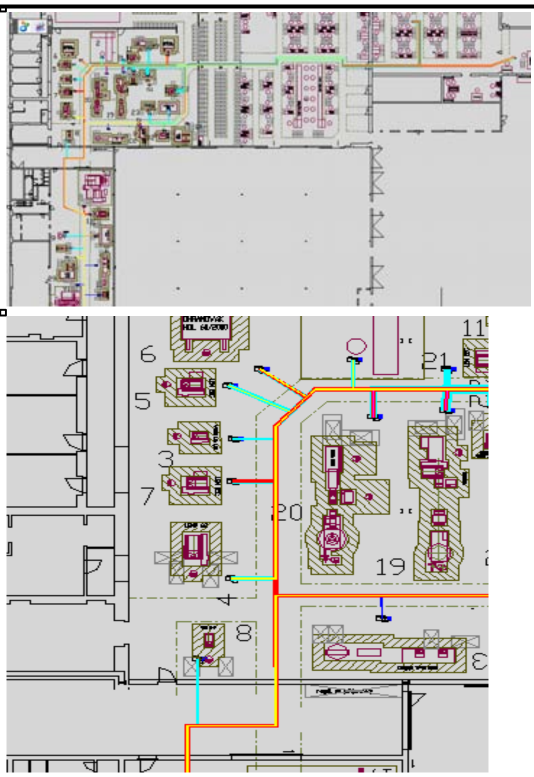
Automatically generated clusters (black rectangular) and material flows



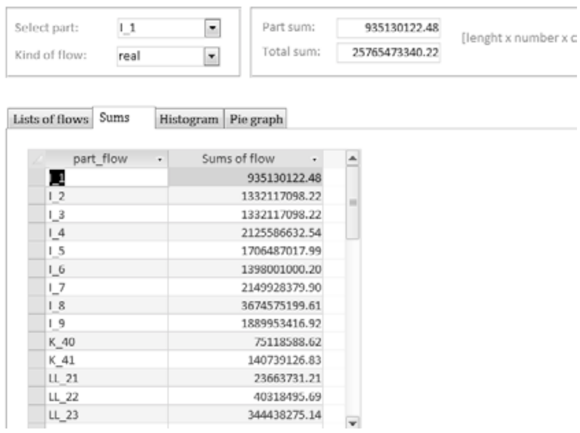
Blocks of real production equipment arrangement



Design of transportation network based on aisles (orange polylines)



Alternative a) overview and detail view



Results of “Cluster” alternative

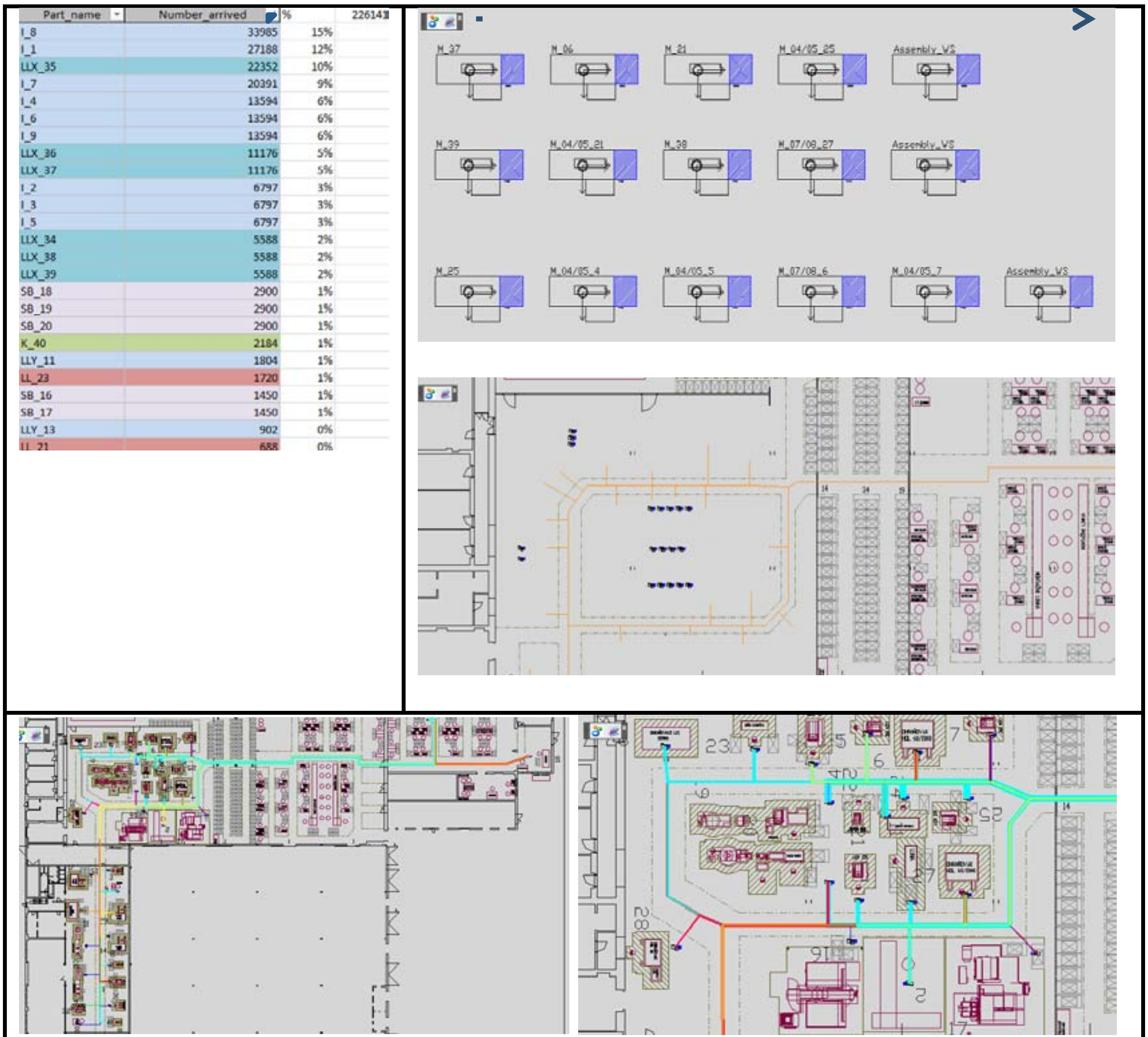
Figure 7 - Cluster analysis and layout design process

Based on the cluster analysis, there are four clusters that are identified, and the rest of the facilities are in the exception field. After that, blocks can be generated in the layout as well as material flows. The next step is to arrange the blocks into symbolic blocks of clusters to represent the real production equipment. Between equipments must be space for transportation (transportation network). Based on that, realistic material flows are generated, resulting a total score of 25 765 473 340 which is 65% of the original. This score has unit flow lengths in mm x products volumes per week x costs per unit.

3.2 Alternative b)“PRODUCTION LINE”

In this alternative, the equipment is placed in the production line by the order of the operation sequence of given parts. It is convenient for the parts with the highest production volumes, as shown in the first image of Figure 8.

For the three parts, simple blocks of equipment are generated into layouts in the order of the operation sequences. The principle of design is similar to the cluster alternative described in the previous section. Blocks are checked for duplicates that are deleted (e.g. Assembly WS). Then, the rest of the facility blocks are placed and, afterwards, blocks representing real equipment are arranged and material flows generated. The total sum of material flows is 27 320 874 005 that is 69% of the original.



Alternative b) overview and detail view

Figure 8 - Production line design process

4 Conclusions

As this simple model has shown, re-layout is very important for the current state of production. Two placement methods were introduced: clusters structure and production lines. Both alternatives can be helpful in decreasing the transportation and manipulation activities by around 30%. In both alternatives the percentage is based on the comparison of the total sum of material flows.

The simulation model and additional experiments done in IDS confirm the use of manipulation equipment and the possibilities for savings.

The suggested alternatives must be discussed with all departments in order to get important feedback, mainly regarding the re-layout costs, such as facility movements, design of electricity network, new logistic elements (buffers) and air supply for pneumatic facilities as well as building limitations – possible floor stress, rebuilding inner walls, ergonomics of workstations, etc.

Usually, the biggest problem is to persuade management to make changes in the current system. It is also very important for the company to make internal scenarios and principles for faster re-layout.

Results of this project were compared with traditional methods used in the company. For this particular project, IDS gave similar results (Havlík, Vavruška, & Koblasa, 2006)(Vik, 2007). The main difference here relates to the time required for the task - IDS required around two working days, while previous methods took four full working days.

In fact, IDS enables a full integration between CAD and Simulation - changes in the production system configuration managed in one of the applications would take effect in the other application. This means that results from the simulations are used to improve CAD layout designs, and CAD layouts data are inputted into new simulation experiments. This process should work iteratively so as to take advantage of the integrated approach. Furthermore, IDS allows the automatic generation of simulation programs and the automatic generation of CAD layouts. This is, really, a strong contribution to industrial community and a powerful message towards an effective use of these two important production tools. AutoCAD and WITNESS simulation tool were the chosen tools for this important purpose (MS Access was the Database system used).

Also, as far as IDS is concerned, the general approach adopted could play different roles towards the innovative contribution of the software tool developed. Thus, the mentioned general approach would enable:

- The possibility of using IDS on different phases and different levels of the design process
- The possibility of using IDS to support design of factories but also to support facility layouts
- The possibility of using IDS as a generic tool (for example to create a base model), but also as a very specific tool (based on the previous model and improving it) for very specific and detailed design problems
- The possibility of using IDS in different types of industrial application areas, but also in the service sector

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Biography

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