Journal of Machine Engineering, Vol. 11, No. 1-2, 2011

Enterprise Resource Planning (ERP)
IDEF0, Systematic Layout Planning (SLP)
Relationship Matrix (RM)

Jevgeni SAHNO[1]
Igor POLYANTCHIKOV[1]
Marina PRIBYTKOVA[1]
Eduard SHEVTSHENKO[2]

MODEL BASED ENTERPRISE MANUFACTURING CAPACITY DEFINITION AND PRODUCT COST ESTIMATION FOR SME

In today's business environment enterprises are trying to establish reorganization changes in their work and organization. It is necessary to structure the existing business to understand all enterprise functions, and change them in order to achieve the main enterprise objectives. To stay competitive under new conditions the external and internal factors should be assessed before restructuring of existing practices. The goal of this paper is to show how to put into practice the process of transition from Small-sized enterprise to Medium-sized enterprise category. For this purpose the existing company data that is stored in the ERP system should be transformed into knowledge. In this paper we consider the conditional “Metal Service” enterprise that produces various metal constructions and plans to produce load lifting equipment (jib cranes, overhead cranes, and additional equipment for existing cranes) for manufacturing enterprises that produce heavy products. The manufacturing capacities of enterprise are defined based on IDEF0 functional model created for each type of product. The simulation results received from these models enables to analyse new production processes, to estimate production time and route for all type of unit and yearly product release. In addition, after the Systematic Layout Planning (SLP) methodology and Relationship Matrix (RM) was applied to simulation results it became possible to calculate new manufacturing area, facilities layout and to assess the new production capacities.

1. INTRODUCTION

To compete in today’s world, companies have to survive in a fast-growing, technologically driven environment of producing goods and services, they must always strive to grow and develop themselves. Today many companies are still use old workshops, work centres and workflows that was intended (some decades ago) for mass production. Before starting to expand production, it is necessary to define what knowledge should be collected to improve the situation. For maintaining a competitive edge, companies must manage its own data and information to compile knowledge that should be used for future strategy development. This knowledge is received from data stored in existing IS systems.

[1] Tallinn Technical University, Doctoral Student at Dept. of Machinery Tallinn, Estonia
[2] Tallinn Technical University, Researcher, Dept. of Machinery, Tallinn, Estonia, eduard.shevtshenko@ttu.ee

In this paper we will consider case of transition from Small-sized Company to Medium-Sized one, which produces load lifting equipment. Firstly, the enterprise SWOT analysis analyzes is done. During this analysis reviewed enterprise products, assessed the existing capacities, determined the right strategy of development and defined future goals and products. Secondly, the IDEF0 methodology is used to build functional models, simulate it, make different scenarios and choose the most suitable ones for every type of product. Thirdly, the Richard Muther Systematic Layout Planning (SLP) approach is applied to the data received from IDEF0 model: machine types and their loading, human resources and production route. It enables to manually design detailed facilities layout for each department in workshop, indicating locations of individual machines, work centers, production areas, and other entities, using Relationship Matrix (RM) and diagram that allows determining the relationship between departments and machines according to the production route. Finally, based on this knowledge the total manufacturing expenditures are calculated. After that it is reasonable to recalculate the new product cost. The cost of final products depends not only from modern equipment, but also from machine relationship and workflow. Figure 1 depicts general scheme of this research paper, from its concept through design research and calculation.

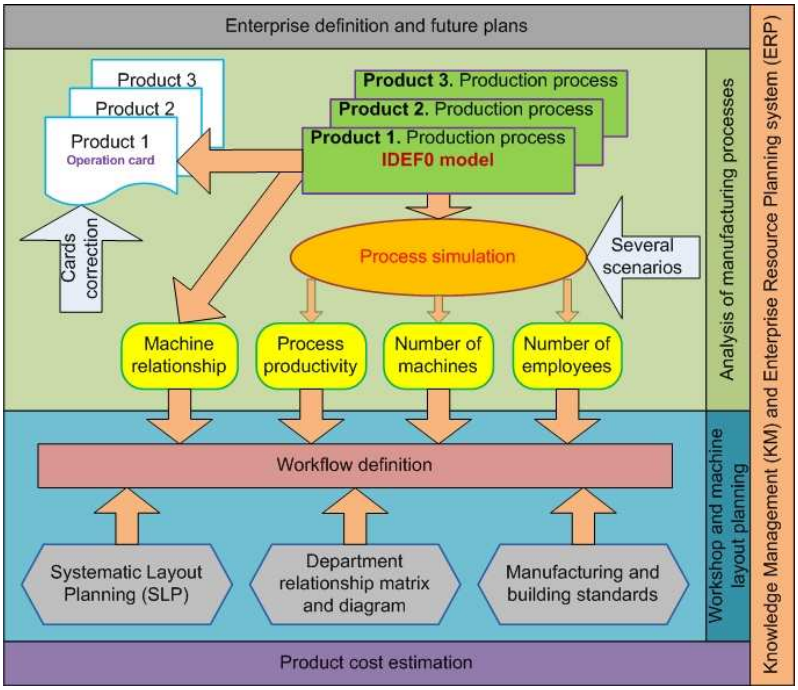


Fig. 1. General Scheme of Article

2. ENTERPRISE DEFINITION AND FUTURE PLANS

Before starting to organize transition from Small to Medium-sized enterprise, it is necessary to clear those definitions. Small and Medium enterprises (SME) - are companies whose headcount or turnover falls below certain limits. These enterprises are the backbone of the European economy and they are a key source of jobs and a breeding ground for business ideas. This classification is shown in Fig. 2.

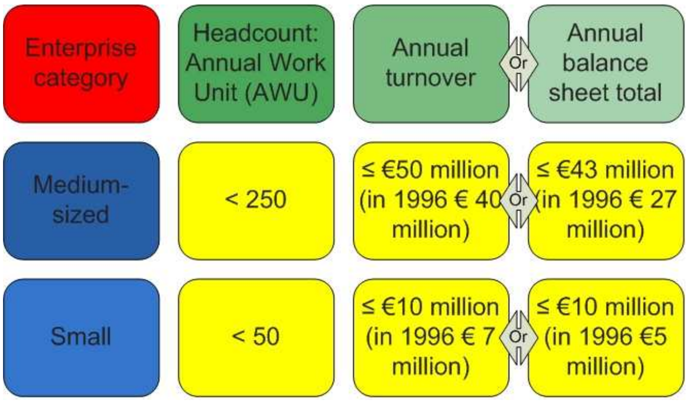


Fig. 2. Category of small and medium-sized enterprises (SME)

Small-sized enterprises are defined as enterprises which employ fewer than 50 persons and whose annual turnover or annual balance sheet total does not exceed 10 million euro. *Medium-sized* enterprises are enterprises which employ fewer than 250 persons and which have either an annual turnover not exceeding 50 million euro, or an annual balance sheet total not exceeding 43 million euro [1].

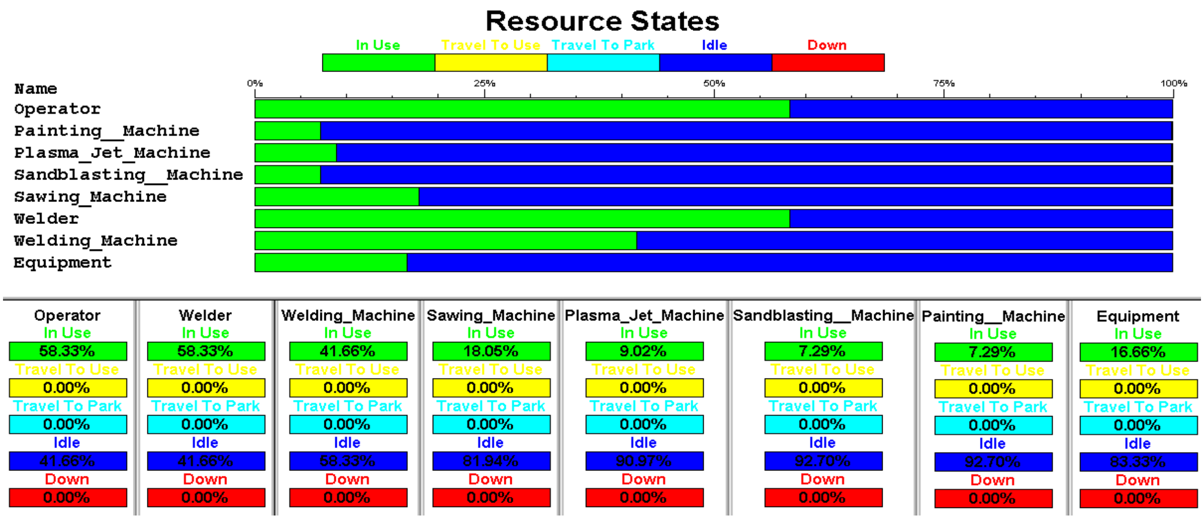
In our case study company “Metal Service” less than 50 persons are employed. In order to fall into category Medium-sized enterprise we need our company to be employed more than 50 workers. In order to calculate how many new workers enterprise needs to start up the production of new product the IDEF0 method is used.

3. ANALYSIS OF MANUFACTURING PROCESSES

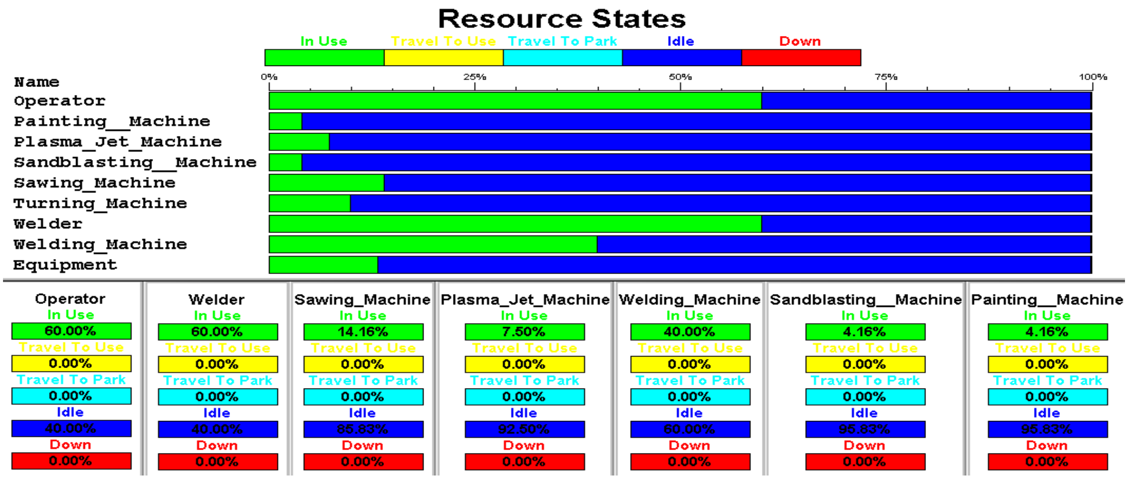
In this paper the Integration Definition Standard for Function Modeling (IDEF0) is used for the enterprise processes modeling. IDEF is a family of modeling languages in the field of systems and software engineering. They cover a range of uses from function modeling to information, simulation, object-oriented analysis and design and knowledge acquisition. These "definition languages" have become standard modeling techniques [2]. Simulation is a powerful and important tool because it provides a way in which alternative designs, plans and/or policies can be evaluated without having to experiment on a real system, which may be prohibitively costly, time-consuming, or simply impractical to do. That is, it allows you to ask "What if?" questions about a system without having to experiment on the actual system itself.

To measure the manufacturing capacities in “Metal Service” enterprise we apply IDEF0 methodology in “WorkFlowModeler” software. Each product is simulated seperately

a. Overhead crane



b. Jib crane



c. Cable drum

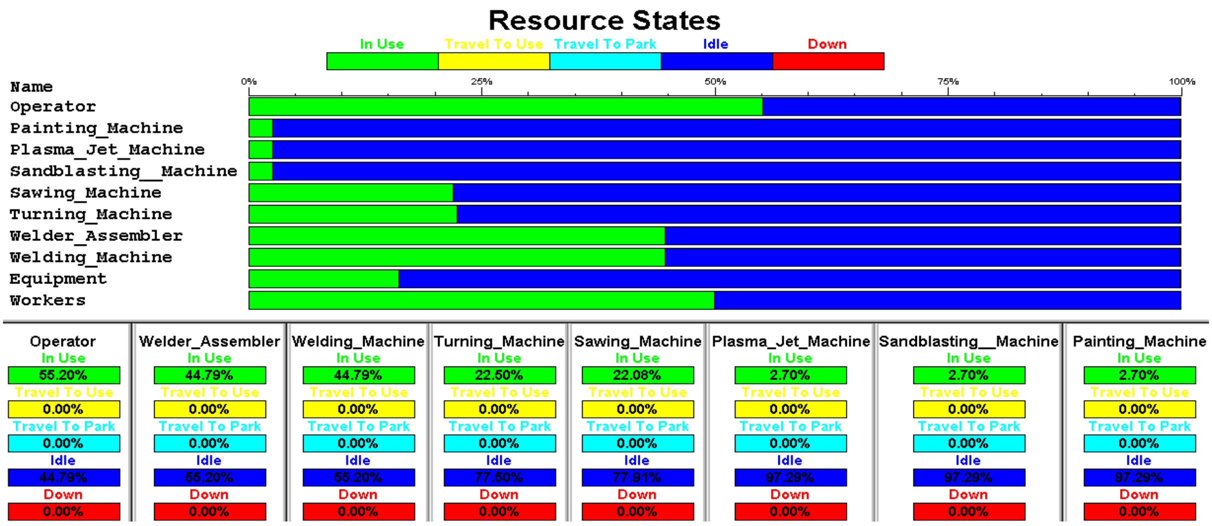


Fig. 3. Simulation results

under several scenarios. After that we start the simulation of all units together (Overhead crane, Jib crane, and Cable drum) in sequential Overlapping Order (OO) and calculate how many products enterprise can release per month and received results are compared. Next figures represent simulation results of each product separately, that show In Fig. 3 the simulation results are given to show the machine and human resources loading.

The results confirm that the production of each unit occurs independently from each other. In the next simulation the products will be produced sequentially using (OO), for example employees will work 168 hours per month.

3.1. SIMULATION WITH OPERATION OVERLAPPING (OO)

In Fig. 4 the common simulation model is presented, that shows production of three units using (OO) with potential reduction in lead time and results. In (OO), the next operation is allowed to begin before the entire lot is completed on the previous operation. This reduces the total manufacturing lead times because the second product production starts before the first product production finishes. The data from simulation model can be transferred to the ERP system for production scheduling.

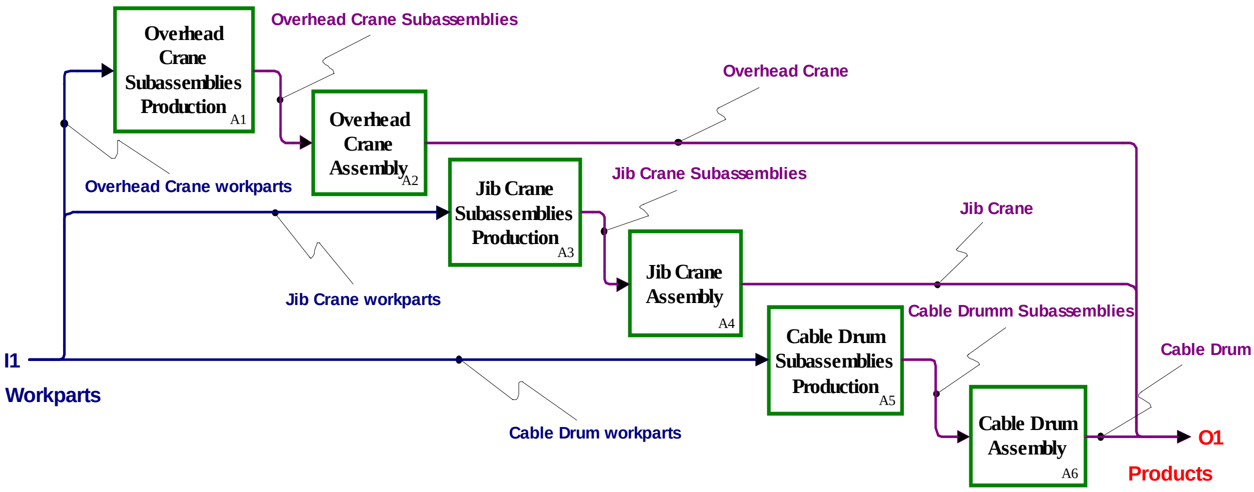


Fig. 4. IDEF0 Common simulation model

In order to use OO the total order should be divided at least into two lots. After the first lot is completed on production A (Overhead crane), it is transferred to production B (Jib crane) and after that forwarded to production C (Cable drum). It is assumed that operation B or C cannot be set up until the first lot is received, but this is not the only case. While operation A is starting with the second lot, operation B is starting with the lot one. When second lot is finished from operation A, it is transferred to operation B. The manufacturing lead time is reduced by the overlap time and the queue time is eliminated [3].

The operation time for used operation is given as: Overhead crane - 24 hours; Jib crane – 20 hours; Cable drum – 40 hours. If the sequential production is used the total production time can be calculated as: 24 + 20 + 40 = 84 hours. At Fig. 5 the IDEF0 scheme of OO unit's production is presented. In such way the assembly operations (Lot 2a, 2b, 2c) are "excluded" and the total production time is: 1200 + 960 + 2340 = 4500 min or 75 worker hors. As the result the 9 hours are saved per one production cycle.

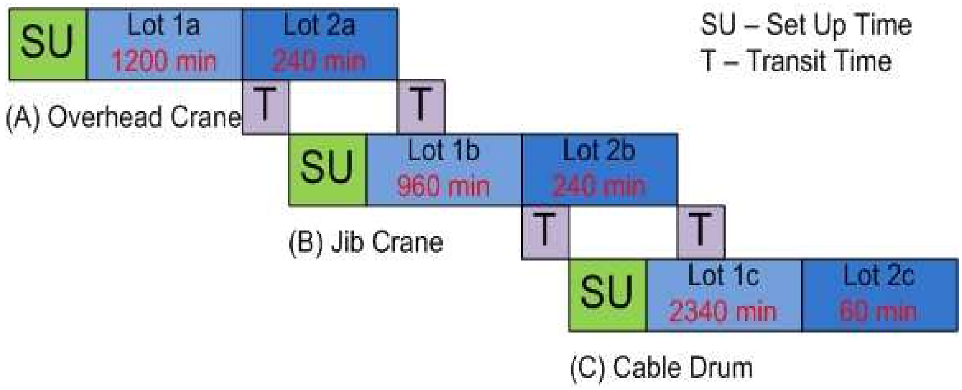


Fig. 5. Operation overlapping

Based on results from IDEF0 model, as shown in Figure 6 that enterprise is capable to produce: (3 + 2) + (2 + 2) + (2 + 2) = 13 units per month when four employees are working in workshop. The quantity of units that could be produced per month is shown on Fig. 6.

Location Name	Scheduled Hours	Capacity	Total Entries	Average Minutes Per Entry
A1 Overhead Crane Subassemblies Production	168	999999	3	1200.000000
A2 Overhead Crane Assembly	168	999999	2	240.000000
A3 Jib Crane Subassemblies Production	168	999999	2	960.000000
A4 Jib Crane Assembly	168	999999	2	240.000000
A5 Cable Drum Subassemblies Production	168	999999	2	2340.000000
A6 Cable Drum Assembly	168	999999	2	60.000000

Fig. 6. Month production of units

3.2. MACHINE RELATIONSHIP DEFINITION

The machine relationship analysis is made to definition the sequence of production equipment allocation. Utilizing WorkFlow Modeler software we can determine the relationships between machines, their sequence of utilization and average loading. The results are given from Arrow Data Base in Fig. 7. Further this data is applied to calculate the workshop area and machine layout. As the loading of machines 4 and 6 is very low they can be used as auxiliary tools and we excluded then from further calculations. Furthermore, using IDEF0 method it is possible to import the routing card into Excel format from Activity Data Base file. The routing cards shows the sequence of production and resource requirement can be calculated.

	A	B	C
1	Machine 1	Sawing Machine	18.10%
2	Machine 2	Plasma-Jet Machine	6.40%
3	Machine 3	Turning Machine	7.50%
4	Machine 4	Drilling Machine	< 3%
5	Machine 5	Welding Machine	42.15%
6	Machine 6	Drilling Magnet Machine	<3%
7	Machine 7	Sandblasting Machine	4.70%
8	Machine 8	Painting Machine	4.70%

Fig. 7. Machine relationship loading and order

4. WORKSHOP AND MACHINE LAYOUT PLANNING

In 1973 Richard Muther has moved the science of facility layout forward with a Systematic Layout Planning (SLP) approach comparable to manual design of facility. Later his research work was concentrated on formalizing the details of the layout process and developing analytical models for certain steps of the SLP procedure. SLP points out the relevant data, decision, and methodologies at each step. In practice, a hierarchical layout approach is often used. The first pass through SLP is to perform the detailed layout for each department, indicating locations for individual machines, staging areas, workbenches, and other entities [4].

4.1 DATA COLLECTION

The process of collecting the relevant data in an accurate form is critical. The political nature of large organizations often makes this process complicated. The data should be collected at the machine level with subsequent aggregation into departments. For instance, data from route card and long-term production plans can be used to determine utilization of each machine type (the number of machines and workers needed) and flows between machines. Route cards are produced during process planning where product dimensions, tolerances, and features are used to select the sequence of machines or work centers visited by the part. Finally, the square area must be allocated to each department. However, if we understand the essential activities of each department, then industrial norms of space, labor, and capital requirements for these activities can be combined with appropriate local adjustments and quantitative resource usage estimates [4] in order to obtain the estimated space requirements.

4.2. WORKFLOW DEFINITION

Prior to tabulating and processing of data into information, we must specify the physical location of work centers. This involves a decision of layout type. Department definitions can be formed around products, process, or cell of similar parts. Flow volumes and patterns must be established Operation process charts are helpful in determining the move patterns for each product. Having these data it is very important to define basic flow type of future workshop because from right decision depend further product productivity, profitability and work flow flexibility. There certain flow patterns are used for movement within and between departments. One of the popular patterns is U-shaped flow in, Fig. 8. Benefits of U-shaped flow are that machines are located close to each other r and the space between them is limited by the size of the machines. Since approximation is important in reducing the material handling time and the operator's walking time between adjacent machines and communication. [5]

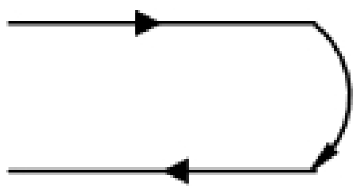


Fig. 8. U-Shaped pattern

4.3. WORK FLOW DESCRIPTION

Taking into account the advantages of U-shaped flow, we can apply this flow to our work centers that will be in workshop. Our simplified model of the plant consist of six work centers: Receiving (Warehouse) and Shipping (R&S), Blank Station (BS), Welding/Assembly Station (WAS), Sandblasting Station (SS), Painting Station (PS) and Quality Control and Packaging (QC&P). Raw materials with purchased standard parts are received to R&S and then transferred to their point of use. A finished product essentially consists of parts that are prepared in BS, and standard purchased parts that are bought and stocked in the warehouse. Finished items and standard parts are sent to WAS, where they are assembled according to the drawings. Then assemblies are moved to SS where they are processed by sand in order to prepare product surface for coating and painting. Then products go to PS, where they coated and painted by base coat and color. Finally, cranes are tested and packaged in QC&P. Any necessary repairs are performed at this point of time. Finished assemblies are sent to R&S, and after that they are shipped to the customer.

After definition what departments are necessary for workshop, their relationship and significance to each other is specified. For instance, shipping and receiving may share common facilities and area. It is recommended to have SS and PS to ensure that the two groups could be expected to communicate directly, at least, more effectively and frequently than if located on opposite ends of the building. Historically, such information is summarized in a Relationship Matrix (RM). Relationships in workshop area are represented in RM that shows the relationship between departments in workshop area as given in Fig. 9.

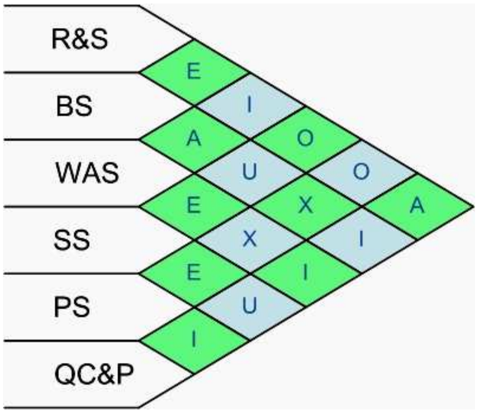


Fig. 9. Department Relationship Matrix

The upper triangular matrix that is often displayed as a triangle. The RM contains a unique diamond for each pair of work centers. Each diamond is usually marked with a value of *A, E, I, O, U*, or *X*, that explained in Table 1. The chart symbols indicate the degree of desirability of locating the two associated departments adjacent to each other in the production facility. As indicated in the figure, the six categories range from “Absolutely necessary” to “Undesirable.” It should be remembered that these ratings are qualitative, and although they provide ordinal rankings of work centers relationships, they cannot validly be used in the standard algebraic operations of addition and summation. Nonetheless, RM is widely used and will be an integral part of department’s layout [5].

Value	Closeness	Line code
A	Absolutely necessary	| | | |
E	Especially important	| | |
I	Important	| |
O	Ordinary closeness	|
U	Unimportant	No connection
X	Undesirable	+

Table 1. Importance of closeness

4.4. SPACE RELATIONSHIP DIAGRAM AND GRID

The space relationship diagram combines quantitative and qualitative relationship data to initiate the determination of the relative location of facilities. A square template is created for each department. Templates are arranged in a logical order. Templates are then connected by lines that communicate the relationship *(A, E, I, O, U,* or X) between department pairs. A sample relationship diagram is shown on Fig. 10 (a). The relationship diagram (b) simplifies the layout problem by assuming all departments are of equal size [4]. This assumption facilitates switching of any pair of departments in order to improve the procedures. The space relationship diagram replaces the equal-sized templates of the relationship diagram with templates proportional in size to departmental space requirements (b). These templates can then be rearranged to find an improved solution to this more realistic problem model.

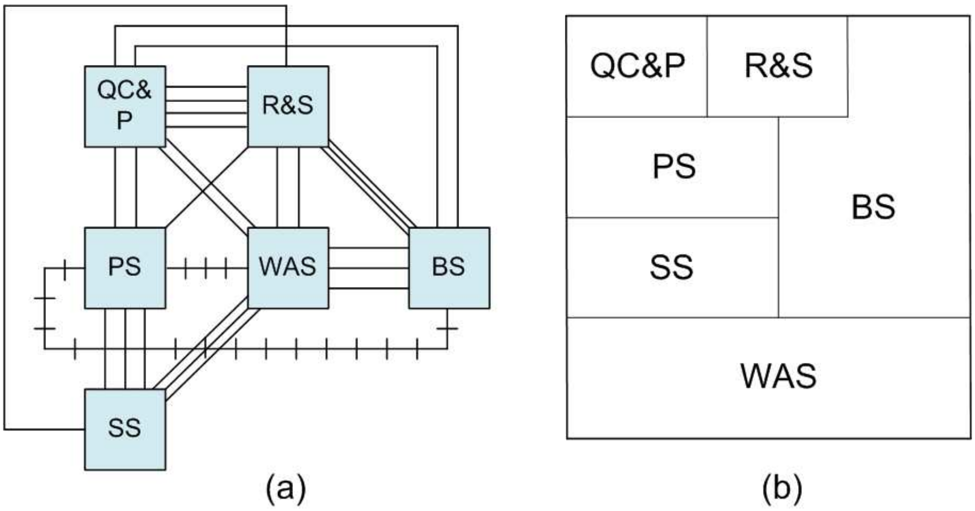


Fig. 10. Initial relationship diagram

From Fig. 4.4a, we see relationship diagram that shows us approximate workshop layout, grid Fig. 10 (b). We did it in order to see how these work centers communicate with each other and than on the basis of this grid we will able to draw final U-shaped workshop layout that is indicated on the Fig. 11.

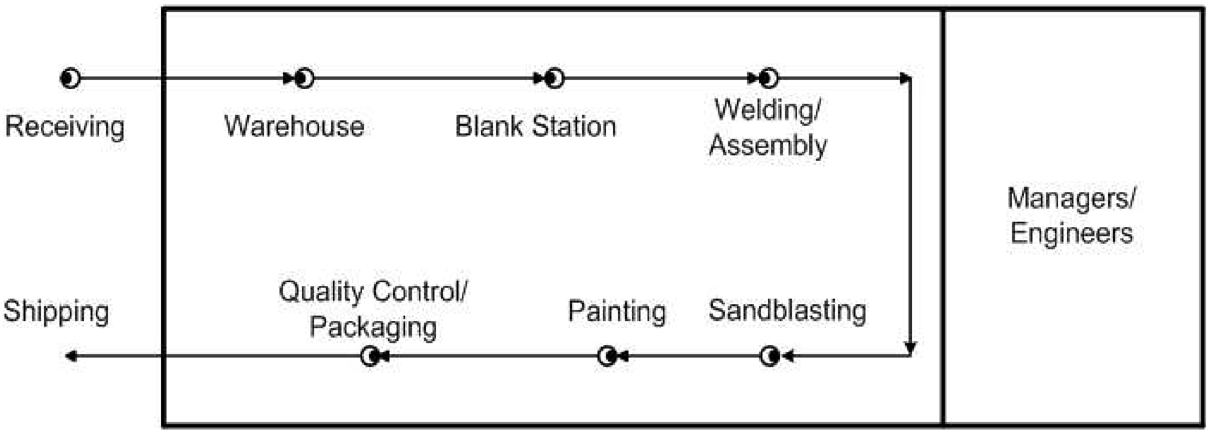


Fig. 11. U-shaped flow process chart

Finally, when workflow is selected and department relationships are defined the space requirements can be calculated based on several methods. Industrial space requirements standards per unit of resource can be applied to the number of workers or machines in the workshop. This approach requires prior listing of the elements, such as machines and storage racks that occupies space. This includes listing machine types, stations and the number required [6].

5. PRODUCT COST ESTIMATION AND FINANCE

Cost estimation is the process of at forecasting the present and future cash-flow consequences of engineering designs and investments. The process is useful if it reduces uncertainty surrounding the revenue or cost element. In doing this, a decision should result that creates increased value relative to cost of making the estimate. Our objects to calculate costs in project environment refer to the functions required to maintain effective financial control over the project throughout its life cycle [7].

Organizations strive to keep their cost under control to ensure their economic health. They implement cost controls procedures to be able respond in the fast and efficient way to changes in the marketplace. Understanding and controlling costs efficiently is an area of growing concern, which require functional management mechanisms that work in harmony with each other. The ERP Product Cost Calculation Module helps to understand and manage planned and real costs associated with products. In product development process the design is spanned to sales stage, the ERP Product Cost Calculation Module manages critical cost factors and performs necessary evaluations and adjustments. The system also facilitates optimal analysis of production costs associated with multiple parameters and related processing.

Unlimited number of parameters can be defined for product cost table, which allows computations using factors such as planned production run quantity, prices, bills of material and exchange rates. Calculation of formulas and linking of parameters with formulas are possible, along with recording of program codes and algorithms, enabling flexible cost calculations. Several types of calculation templates are available, with the help of parameterization of such factors as activity types, cost components, and general expense ratios. Calculations may be executed for a complete product or for a single component. Alternative calculations may also be performed and results may be compared for costs [8].

6. CONCLUTIONS

In this paper the process of transformation from Small-sized enterprise to the Medium-sized enterprise is presented. The “Metal Service” plans to expand production in order to produce additional products - load lifting equipment. For this purpose the following methods and tools are applied: IDEF0, ERP, SLP and RM. Before making transition from Small to Medium-sized enterprise, first of all, we have collected data from existing enterprise and processed it into knowledge. The utilizing all necessary knowledge and enterprise plans the IDEF0 simulation model is built. Then the several simulation scenarios are used and in order to find suitable outcome. IDEF0 simulation results represented us new production route, time, necessary human resource, machine quantity and loading and work flow. Received data enables to use SLP method and RM for equipment allocation in proper sequence accordingly to the production route. The industrial standards were applied to calculate work centers and workshop area. Finally, The ERP system was used to calculate new product cost. It is concluded that the right and flexible work flow and rational machine usage directly reflected in product cost. The product cost can be decreased by minimization of production expenditures and elimination of bottlenecks.

ACKNOWLEDGEMENTS

Hereby we would like to thank the Estonian Ministry of Education and Research for targeted financing scheme SF0140113Bs08 that enabled us to carry out this work.

REFERENCES

[1] The new SME definition., 2005, *User guide and model declaration*, Enterprise and industry publication. European Commission

[2] Standard IDEF0., 1993, Draft Federal Information Processing Standards Publication 183, 21 Announcing the Standard for INTEGRATION DEFINITION FOR FUNCTION MODELING.

[3] J. R. ARNOLD., 2003, Introduction to Materials Management (Third Edition).

[4] RONALD G ASKIN, CHARLES R. STANDRIGE., 1993, *Modeling and analysis of manufacturing systems*.

[5] JAMES A. TOMPKINS, JOHN A. WHITE, YAVUZ A. BOZER, J.M.A TANCHOCO., 2003, Facilities Planning (Third edition).

[6] E.S.JAMPOLSKI., 1975, Design of machining factories and workshops, (Проектирование машиностроительных заводов и цехов) (Issue 4), Moscow.

[7] ADEDEJI BADIRU., 2006, Handbook of Industrial and Systems Engineering, CRC Press Taylor & Francis Group.

[8] http://www.canias.com/solutions/canias-cal1.html.