The Influence of the Planning Process Integration on the Material Flow Efficiency

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Abstract. The research presented in the article is intended to identify dependencies between the planning process integration level and the material flow efficiency in production enterprises. The SOP (Sales and Operations Planning) method was applied in the research on reflecting the planning process integration. In order to achieve the aim the authors performed quantitative research by means of simulation studies and statistical research analysis. A model of integrating planning processes in production enterprises based on the SOP method was developed for the sake of this research. The understanding of material flow efficiency was also defined. All the elements were modelled in the iGrafx Process for Six Sigma software by means of BPMN notation. The simulation studies were performed with respect to dynamic environment conditions. The result analysis of the studies was conducted using the method of testing statistical hypotheses in the Minitab 17 software. The analysis results make it feasible to state that the increase in the planning process integration causes an increase in the material flow efficiency.

Introduction

Contemporary supply chains are oriented to fulfilling customers’ needs. The needs are characterised by a large modification dynamics and result in agility of management systems [12]. The customers expect a high availability of products accustomed to their needs. The large market competition causes supply chains to deliver the products at possibly lowest prices. This implies a necessity to diminish operational costs. A particular role in supply chains is played by the production enterprises which execute the make-to-stock strategy (producing standard products based on the developed sales forecasts). It is required by the enterprises’ activity to involve large financial outlays. The enterprises are less elastic than commercial enterprises due to their specifics and the cost indices of technological processes. Therefore, it is so important to enhance their material flow efficiency. According to the state-of-art knowledge the process integration in supply chains has a positive impact on their efficiency, and increased level of logistics excellence [7]. By reference to the production enterprise objectives it is assumed that the customer service level maximisation with a positive return on sales is a major objective of an enterprise which executes the make-to-stock production strategy in the high competition conditions.
The research as described in this article was intended to identify the planning process integration influence on the material flow efficiency in the production enterprise. The definition of the material flow efficiency made it possible to formulate 2 research hypotheses:

H1: The increase in the planning process integration level in the production enterprise causes an increase in the customer service level.

H2: The increase in the planning process integration level makes it feasible to improve a return on sales of the production enterprise.

In order to verify the research hypotheses the authors developed a model of integrating planning processes in the production enterprise (based on the SOP method and quantitative research conducted in Polish production enterprises). Then, the model was transferred to a simulation environment by completing it with the business environment. By using the simulation model one received results in the form of the levels of customer service and a return on sales in the case of various planning process integration levels. The results underwent a statistical analysis oriented to verifying the research hypotheses. The research methodology stages are presented in consecutive article chapters.

Planning Process Integration

Planning process structures in production enterprises are very complicated structures. This is implied by a variety of the processes executed in the enterprises. The authors paid attention to the planning process integration at the tactical level by limiting the research scope. The definition of planning at the tactical level by APICS equates the tactical plan with the sales and operations planning (SOP) [4]. According to the same dictionary SOP is defined as [4]: the process bring together all the plans for the business (sales, marketing, development, manufacturing, sourcing, and financial) into one integrated set of plans. It is performed at least once a month and is reviewed by management at an aggregate (product family) level. (…) It is definitive statement of the company’s plans for the near to intermediate term, covering a horizon sufficient to plan for resources and to support the annual business planning process”. Interesting definitions of SOP might be found in the works by [8, 14]. In the reference literature there are numerous works that mention SOP implementation advantages. In the reference research the case study method was frequently used. In their work Collin and Lorenzin [5] presented results that would indicate that the SOP implementation makes it possible to enhance the supply chain elasticity. However, it is necessary to organise internal processes to implement SOP [11]. Survey research is a frequent method in the SOP area. The research presented in the works by [9, 10] indicate that the coordination of planning and operational processes enables more efficient process improvement and the increase in the integration level in decision-making processes by sales and production functions has an influence on improving the production enterprise efficiency. The application of the modelling and simulation method in the research in the SOP area was presented i.a. in the work by [6]. This team of authors developed mathematical models that would make it possible to specify the results of the SOP planning implementation in the case of the MTO production strategy conditions. The results indicate that the SOP plan implementation in the MTO production strategy makes it feasible to diminish production costs and to maintain a certain customer service level at the same time. In the work by [3] there is a simulation study which is intended to identify an effect of the SOP plan coordination in the supply chain. The reference literature lacks simulation studies that would make it possible to obtain quantitative empirical data. The data illustrate the SOP plan functioning in the MTS production strategy conditions.
Research Model

One might distinguish three fundamental parts in the developed research model:
- model of the planning process integration in production enterprises,
- model of environment factors,
- model of operational processes executed by production enterprises.

The most significant element of the developed research model is the model of integrating planning processes in production enterprises. The model was formed based on the results of literature research and the empirical research performed among 149 production enterprises in the territory of Poland. A detailed description of the results of the research on the planning process integration in the active production enterprises in the territory of Poland is presented in [2]. Table 1 includes a qualitative description of the planning process integration levels which is developed for the sake of the research model.

Table 1. Modelling of integration of planning process.

<table>
<thead>
<tr>
<th>Planning process integration level</th>
<th>Characteristics of level</th>
</tr>
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<tbody>
<tr>
<td><strong>D</strong></td>
<td>No planning process integration, production plan developed adaptively to the sales plan, available resources at a constant level in the process duration based on standards specified in the past, no financial plan and marketing actions included in the plan</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>Corrective procedures implemented in the area of the sales and production planning and in the area of production and procurement. The objective of the procedures is to select the most appropriate solution to executing the proposed sales plan in terms of the planned profit and return on sales by the financial plan simulation, available resources specified at a constant level in the process duration based on standards specified in the past, no marketing actions included in the plan</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td>Corrective actions as at level C with the financial plan, available resources specified based on real data about repairs and/or developing the resources as a result of the conducted investment actions, no marketing actions included in the plan</td>
</tr>
<tr>
<td><strong>A</strong></td>
<td>All the actions conducted as at level B without the marketing plan. At integration level A the marketing plan is formed based on real data (plan promotional campaigns, extending and enlarging market areas, product portfolios, etc.). The plan is included in the planning process structures and therefore influences the material flow plan which is under construction.</td>
</tr>
</tbody>
</table>

The quantitative characteristics of particular planning process integration levels is included in the process approach to the developed model. This is presented in Table 1.

The environment conditions were decided to be reflected in the research model due to their significance identified both in the literature research and in the authors’ own research. A parametric model was used in the above identification. In the model the following business environment parameters are reflected: influence of marketing actions on sales volume, random variation of demand, demand seasonality, demand trend, random fluctuations of demand, a supplier’s potential. The influence of the maintenance-repair plan on the production potential availability is considered to be an element of the planning processes in the production
enterprise. The potential was also regarded to be a business environment parameter. Each of 7 parameters might appear in one of 3 states: low, medium, high. Numerical values are assigned to each state.

The model of operational processes executed by production enterprises was developed by patterning it upon the SCOR supply chain referential model. The decision to select this model was made based on its comprehensiveness, universality and interconnections between process aspects with their measures.

Such a model was developed in the conceptual approach and implemented in the iGrafx Process for Six Sigma simulation environment. More information on the research model is presented in [1]. In the reference literature there are numerous definitions of efficiency, i.a. production efficiency [13]. It is assumed that the efficiency will be referred to the process measures and will be defined as a sum: effectiveness measured by service level indicator - OTIF and efficiency measured by return on sales (called later efficiency measures). This is due to the fact that the focus is put on the process approach both to planning and material flow.

Simulation Studies

8 variable parameters are included in the simulation experiment plan. The planning level was the most important. According to the developed model the planning level might have appeared in one of 4 distinguished states. The 7 remaining parameters that reflected the enterprise environment might have reflected one of 3 states. The simulations were performed based on random demand throughout the year. The demand distribution was in accordance with the normal distribution. In order to eliminate the influence of a random factor on the results the study was decided to be performed within 10 iterations. Due to the above fact and parameter number and parameter states the number of performed simulations was 87 480.

Then the results in the form of the performed customer service level and the obtained return on sales in the case of each simulation were aggregated to 4 groups. The groups corresponded to the defined levels of the planning integration levels. The aggregation was performed by enumerating an average value of each of efficiency measures in the case of particular planning process integration levels.

A statistical result analysis was conducted in 2 stages. The first stage was devoted to checking whether there is a correlation between the planning process integration level and efficiency measures. To perform it, one calculated rho-Spearman correlation value in the case of each data set (separately in the case of the customer service level and return on sales). Table 2 includes the analysis results with the specification of the statistical test significance.

<table>
<thead>
<tr>
<th></th>
<th>Spearman rho</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service level (OTIF)</td>
<td>0.760</td>
<td>0.000</td>
</tr>
<tr>
<td>Return on sales</td>
<td>0.260</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Source: Own study

The results in Table 2 show there is a correlation between the planning process integration level and the adopted result measures. In addition, the p-Value indicator value is smaller than the adopted significance level (α=0.05). This means that the correlations are statistically significant. As the correlation exists, it is possible to make a transition to the second analysis
stage. Its objective is to specify whether each planning process integration level increase (each transition between 2 consecutive levels) has an influence on improving the customer service level and return on sales. In order to prove this, one used the Minitab software and the 2-sample t test method. As to each pair of consecutive planning process integration levels (A-B, B-C, C-D) one formulated a few statistical hypotheses concerning an average value of each efficiency measure.

\[ H_0: \mu_1 - \mu_2 = 0 \]
\[ H_1: \mu_1 - \mu_2 > 0 \]  

Simultaneously, one verified 6 pairs of statistical hypotheses – 3 pairs in the case of each efficiency measure. The hypothesis test results are presented in Table 3.

Table 3. Spearman rho for efficiency measures.

<table>
<thead>
<tr>
<th>Planning process integration levels</th>
<th>p-Value for Service level (OTIF)</th>
<th>p-Value for Return on sale</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-B</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>B-C</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>C-D</td>
<td>0.001</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Source: Own study

The p-Value indicator values in the case of each hypothesis pair make it possible to reject a null hypothesis in favour of an alternative hypothesis (adopted \( \alpha = 0.05 \)). This means, the alternative hypothesis values are higher in the case of higher planning process integration levels independently of the efficiency measures (H1 and H2 research hypotheses proven).

**Summary**

As part of the conducted simulation research, the following 2 research hypotheses were positively verified:

H1: The increase in the planning process integration level in the production enterprise causes an increase in the customer service level.

H2: The increase in the planning process integration level makes it feasible to improve a return on sales of the production enterprise.

The above statement was compiled with the definition of the material flow efficiency as adopted for the sake of the research. This might lead to a conclusion that the planning process integration has a positive impact on the material flow efficiency (efficiency defined as a sum of effectiveness and efficiency). Therefore, it should be stated that the production enterprises, which are willing to increase their operational activity efficiency (related to the efficiency of material flow), need to orient their actions to the planning process integration. By reference to the simulation studies it should be stated that the high integration level (related to obtaining information from the supply chain partners according to the developed model) has an especially important influence on the material flow efficiency. Thus, it might be presumed that the process outside integration is much more efficient than the internal integration. The outside integration is performed between the enterprises which cooperate within the supply chain. In the author’s opinion the above observation might be a base to do further research work.
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