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Use of system dynamics tools in value-oriented approach in management

Abstract

The article is based upon assumption that in search for best sustainability any organization is leaning towards the value-oriented approach in management. This approach is grounded in the stakeholder theory, and addresses needs and expectations of consumers and other stakeholders on a long-term basis. When contributing to the best practices, companies produce shared values, able to act as a social power, to enter into the public consciousness, and to transform into behavioural norms. At the same time, these practices support best handling of resources and opportunities thus leading companies to success.

The system dynamics model presents enterprises with potential strategies grounded in the target indicators, provides objective assessment of the target indicators sensitivity to changes at one or several parameters, sets and corrects their controllable limits, identifies specific causes of variation and, thus, insures necessary adjustments to the business management.

Today, the system dynamics modelling is supported with mathematical software: Maple, MathCAD, Maxima, AnyLogic, Vensim, iThink (computer experiments software).

In our research, we support the idea to develop methodology and improve practices of value-oriented approach in organization management based upon key tools of process efficiency, i.e. the system dynamics model. To build a system model and to run simulation analysis, we used AnyLogic software system.

In this research, system dynamics model is tested against the case of supply chain management in the food industries, which include production facilities of high seasonal demand and products distribution network.

To meet volatile demand, the company keeps certain stock of products in the chain of regional warehouses, and shipping the products as soon as new order is received. The market conditions and customer requirements are such that if the products cannot be shipped to the customer on time, then they buy these products from other sources. the system works steadily and does not require adjustments. Minor fluctuations in demand also do not break the system's balance. The system works steadily and does not require adjustments. Minor fluctuations in demand also do not break the system's balance.

Simulation of seasonal demand increase (40% seasonal upsurge) proved the rate of new production shifts is almost twice higher than that of demand and two times smaller than the production cycle length.

The experiment draws us to the following conclusions. The first response to increased demand is the shrink of stocks due to the delivery delays because of the duration of production cycle. A natural reaction of the company to such sharp reduction in stocks is striving for extreme intensification in reply to the demand upsurge. This causes a multiplicative effect. Since the stocks are initially shrinking, the only way to meet such shortfall is to raise the production rate above the shipments rate. The production shall exceed the shipments rate by sufficiently in volume and time to replenish the stocks in full. The launching peak value should lag behind the moment when the demand increases. The output adjustment reaches maximum at the moment when the stocks reach its minimum. The stocks start to grow only when the output rate exceeds the shipments rate which is always with delay.

The research concludes on how to assess the response of targeted strategic indicators to the changes in one or more parameters of the system dynamics model. Our conclusions also help to determine controlled variation limits of the key performance indicators and causes of variation, and hint on how to implement rational adjustments as well.

The application of system dynamics tools in performance forecasting to better address customers and other stakeholders' expectations and needs would allow enterprises to introduce value-oriented approach in management on a long-term balanced basis and to strengthen their competitive advantages.

Keywords: Value-Oriented Approach; Management; System Dynamics; Enterprise; System; System Dynamics Tools; Food Industry
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Застосування інструментів системної динаміки при реалізації ціннісно-орієнтованого підходу в управлінні

Анотація
Автори розглядають ціннісно-орієнтований підхід до управління як результат розвитку стейкхолдерської теорії. На думку авторів, компанії беруть участь у створенні спільних цінностей, коли запроваджують або розвивають кращі практики оптимізації ресурсів і можливостей. У статті обґрунтовано необхідність розробки методології та вдосконалення практики реалізації ціннісно-орієнтованого підходу в управлінні сучасною організацією за допомогою ключового інструменту процесної ефективності – моделі системної динаміки, та її окремих інструментів, причинно-наслідкових і потокових діаграм, системи кінцево-різницевих рівнянь. Викладено результати застосування моделі системної динаміки в управлінні ланцюжком поставок компанії, в структуру якої входить виробниче підприємство харчової промисловості з вираженою сезонністю попиту й мережа дистрибуції виробленої продукції. За результатами імітаційного моделювання сезонного підвищення попиту зроблено висновок, що темп зміни випуску й запуску в виробництво продукції перевищують попит майже вдвічі і запізнюються в часі більш ніж на тривалість двох виробничих циклів. Результати дослідження розширюють знання про можливості визначення контрольованих меж варіації ключових показників ефективності та причин варіації, а також про способи реалізації раціональних коригувальних дій.
Ключові слова: ціннісно-орієнтований підхід; управління; підприємство; система; системна динаміка; інструменти системної динаміки

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Применение инструментов системной динамики при реализации ценностно-ориентированного подхода в управлении

Аннотация
Авторы рассматривают ценностно-ориентированный подход к управлению как результат развития стейкхолдерской теории. По мнению авторов, компании участвуют в создании общих ценностей, внедряя и развивая лучшие практики оптимизации ресурсов и возможностей. В статье обосновывается необходимость разработки методологии и совершенствования практики реализации ценностно-ориентированного подхода в управлении современной организацией с помощью ключевого инструмента процессной эффективности – модели системной динамики и ее отдельных инструментов, причинно-следственной и потоковой диаграмм, системы конечно-разностных уравнений. В работе представлены результаты применения модели системной динамики в управлении цепочкой поставок компании, в структуру которой входит производственное предприятие пищевой промышленности с выраженной сезонностью спроса и сеть дистрибуции произведенной продукции. По результатам имитационного моделирования сезонного повышения спроса сделан вывод, что темп изменения выпуска и запуска в производство превышают спрос почти вдвое и запаздывают более чем на двукратную длительность производственного цикла. Результаты исследования расширяют знания о возможностях определения контролируемых пределов вариации ключевых показателей эффективности и причин вариации, а также о способах реализации рациональных корректирующих действий.
Ключевые слова: ценностно-ориентированный подход; управление; предприятие; система; системная динамика; инструменты системной динамики

1. Introduction

Amid the increased dynamics of business processes and growth in uncertainty of the business environment, to run appropriate analyses of socio-economic processes at macro and micro levels is getting ever more challenging. As descriptive theories often fail to meet this challenge, prescriptive theories are turning the tide [1, p. 15]. Their application is especially promising to address issues of better resource allocation and configuration of operational capabilities of the enterprise.

Today, the best experience in corporate management (G20 / OECD Principles of Corporate Governance, EU Action Plan), management accounting (Global Management Accounting Principles, PAS1919), and sustainable development (Global Reporting Initiative, AccountAbility) is constantly reassessed and updated.

The modern organization which introduces the best practices of management is seen as a vehicle of certain values, important for consumers and other stakeholders. The focus on the best practices as common values and factors of

development does several important things for the organization as argue, for instance, A. N. Petrov (2017) and V. S. Katkalo, C. N. Pitelis & D. J. Teecey (2010):
- precludes the problem of targeting instability;
- identifies innovation directions and aims of innovative development;
- meets the dichotomy of strategic management - to ensure sustainability and adapt to constant changes in dynamic business environment, management and entrepreneurship, competition and cooperation [1, p. 14; 2, p. 1177].

Business determines satisfaction of its participants. So, if this satisfaction depends on motivation and way to achieve results, then the values immediately represent these drivers [3, p. 162].

Within modern business dynamics value-oriented approach is treating business organization under the following provisions:
- management decisions must be compliant with the contemporary evolution of social values;
- value-orientation should be the matter of consideration and implementation in each type of activity by business organization.
- Introduction and development of best management practices is instrumental for the shared values, defines measurable, assessable, and manageable goals and related indicators of business activities.

2. Brief literature review

Sustainable business success is directly determined by the company's values, its ability to meet the needs and expectations of its customers and other stakeholders on a long-term balanced basis.

This definition introduced in ISO 9004:2009 «Managing for the sustained success of the organization - A quality management approach», connotes with the stakeholder theory as interpreted by J. E. Post, L. E. Preston & S. Sachs (2002) in their «Redefining the Corporation: Stakeholder Management and Organizational Wealth». They define wealth as a special integral indicator of the company's ability to produce various benefits for all its stakeholders within a long period of time [4, p. 45]. R. E. Freeman (1984), a father of the stakeholder theory, saw the company's stakeholders as any individual, group or organization that have a significant impact on the decisions made by the company and /or are influenced by these decisions [5].

According to as declared in AA1000 standards series, distributed by non-profit organization «AccountAbility», the stakeholder concept of corporate management, i.e. the Stakeholder Relationship Management (SRM), is focused on the way stakeholders participate in the management process, in business decision-making processes.

As the stakeholder theory progressed, it led to the development of value-oriented approach in management, which is «more progressive in the content and more comprehensive in the tool set» [6, p. 62].

While in the 1990s this approach focused, as M. Porter (1998) pointed out, at value chains, in 2000s the emphasis shifted towards the concept of Creating Shared Value (CSV), introduced by M. Kramer (2007) [7-8].

According to M. Porter (1998) certain types of business activities, aimed to create values, were combined into a chain. The apex of such chains was in their final output, defined by the price at which manufacturers could sell their products, and consumers - purchase them [7]. Weakness of Porter's original model was in its obvious disregard of the organizational mechanism for creating sustainable competitive advantages - the company's «dynamic capabilities pool», i.e. its business orientation, continuous search for the sources of customer loyalty, organizational training, optimization and automation of business processes, innovative activity and corporate social responsibility [9, p. 42]. In the article «Creating Shared Value: Rethinking Capitalism and The Role of Corporation in Society» M. Porter & M. Kramer (2011) emphasize that the concept of shared value production is the basis for the whole new set of best practices that all companies should follow [10, p. 72].

Only within such context the company's values acquire social power, enter public consciousness, and turn into behaviour patterns. At the same time, best practices should be handled in dynamic way, since technologies are becoming obsolete, new market requirements emerge, physical assets are devalued, and organizational approaches are changing (Freeman, 2013) [11].

Some authors replace the category of values with the «concepts of competence, utility and adaptability», implying «the ability to qualitatively and quantitatively assess the effectiveness of enterprise or its subsystem» and «the enterprise's ability to obtain new qualities when exposed to environmental factors that affect its components through functional competences» [12, p. 86].

Meanwhile, value creation for business and society is not limited to social investment and corporate social responsibility (CSR), as it is mentioned in some publications [13, p. 67]. Of course, the well-managed companies are also making efforts to establish, maintain, improve and systematize communication channels, dialogue and constructive interaction with all stakeholders, implementing the principle of «the triple bottom line»: the outcome is seen as combination of financial (profit) social, and environmental results.

In the stakeholder theory, the concept of value-based management (VBM) is common and treated as an input to maximizes expected long-term value (cost) of the company. Under this approach, as noted by T. Copeland, T. Koller, & T. Murrin (2015), the cost seems to be the least conflicting criterion in perceptions by the company and its stakeholders, since the owners are naturally interested and responsible for the state of business and satisfaction of other interested parties [14, p. 3-5].

However, against the backdrop of changing market and its imperfections, this argument is not confirmed by practice: the companies are prone to «deviant» behaviour, and the management often focuses on wrong financial models and fails to determine essential competencies properly [15, p. 121; 16, p. 40].

As a method to overcome extreme complexity of decision-making regarding the organization's environment transformation, values and expectations of stakeholders, future demands for resources and technologies, the system dynamics tools are widely appreciated Forrester (1958) [17].

At the present time, Consumer Sentiment Index (University of Michigan's Consumer Sentiment Index, CSI), Consumer Confidence Index, Conference Board Employment Trends Index, business activity indices (PMI Manufacturing, PMI Services / PMI non-manufacturing) are regularly regarded as criteria for system dynamics models in business cycle studies and macroeconomic forecasting of the national economies. Thus, University of Michigan provides traders with up-to-date information on consumer sentiments index, impacting financial and stock markets [18].

Some renowned in system dynamics like J. D. Sterman (2000), K. D. Warren (2008), H. Rahmandad (2015), are insisting on integration of the strategic management concepts into dynamic modelling, including search for best practices through simulated dynamic modelling [19-21].

Based upon use of system dynamics models to assess corporate practices, some implications were observed:
- staff motivation increased by 5%, followed by a 1.3% growth in customer satisfaction and a 0.5% revenue [22];
- fully engaged customers produce, on average, 23% better indicators of profitability and return [23].

Other interesting findings were obtained by A. Trachuk & N. Linder (2018), as they noted that innovative investments enhance the performance of industrial companies within range of 0.03 to 0.16, depending on the volume of investment in R&D [24].

3. The purpose of the article is to adapt the system dynamics tools for the study of value-oriented approach in management when forecasting the company's performance regarding customer and other stakeholders' satisfaction.

4. Results

The system dynamics gives the means to incorporate empirical indices of employee satisfaction, consumer and other stakeholders' expectations in the outcomes of business activities into and company behaviour models.

The dynamics also involves the following stages of research. First, the system is delimited from the environment and cause-effect links between the system's variables and elements are established (Causal Context Modelling, or CCM). S. N. Grösser (2017) emphasizes that this approach is an integrative, qualitative, cross-disciplinary, able to produce qualitative description of the system, including the key variables of correlation and system scope [25]. A special focus is put on reactions. This research stage include elaboration of the causal diagrams, i.e. causal reaction loops (causal-loops diagrams) between different target criteria, when one variable, reaching particular critical value, affects the value of another (direct relationship) with time delay, followed by the change of the first one (feedback). For such cycles, time delays (delay), from the moment of decision-making to the effect, and then, between the effect and the moment of a new decision made under the information influence, are extremely important.

Later the stock and flow diagrams are built. The main elements of the model are stocks (materials, knowledge, people and money), streams and dynamic variables. Within the value-oriented approach, it is important to note that the parameters of the system dynamics model can include the information collected, and estimates of subjective probability of occurrences within a given time.

Finally, a set of causal and flow diagrams is supported by the system of finite-difference equations, integrated according to Euler or Runge-Kutta scheme. That allows quantification of the causal relationships between the target criteria and indicators, and assessment of dynamic changes in the final results, with regard to the parameters of delays and gains.

This model is used to run a simulation, producing scenarios for further decision making.

The system dynamics model presents enterprises with potential strategies grounded in the target indicators, provides objective assessment of the target indicators sensitivity to changes at one or several parameters, sets and corrects their controllable limits, identifies specific causes of variation and, thus, insures necessary adjustments to the business management.

Today, the system dynamics modelling is supported with mathematical software: Maple, MathCAD, Maxima, AnyLogic, Vensim, iThink (computer experiments software).

Among other sectors, system dynamics approach has been used by scholars to analyse the activities of food industry companies, that combine both manufacturing and products distribution facilities. The demand for their products is generally growing, and has seasonal nature. Technological process is characterized by the fact that the products are manufactured in fixed volume batches and with limited expiry date.

To meet volatile demand, the company keeps certain stock of products in the chain of regional warehouses, and shipping the products as soon as new order is received. The market conditions and customer requirements are such that if the products cannot be shipped to the customer on time, then they buy these products from other sources.

This imposes strict requirements for the decision-making terms within the supply chain management [26]. Despite relative autonomy of the company's divisions, the decisions must be coordinated, and the prominence of customer demand is accepted to the full extent by each of them.

To build a system model and to run simulation analysis, we used AnyLogic software system. In particular, with the help of AnyLogic, the final product marketing subsystem model has been suggested (Figure 1).

The interrelationships of storages, flows and variables of the subsystem model presented in Figure 1, can be described by the following mathematical model:

$$d(stock)/dt = rateProd - rateShip\,, \qquad (1)$$

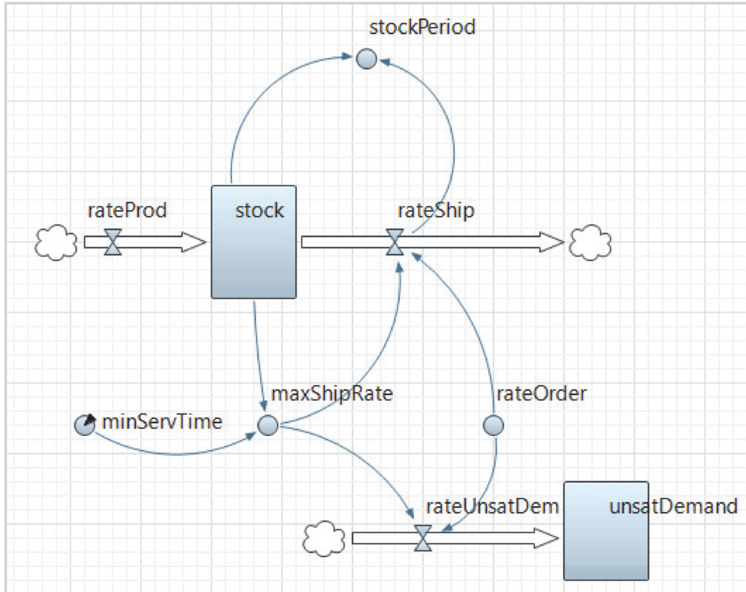

Fig. 1: **Stock and flow diagram of finished product marketing subsystem**
Source: Developed by the authors

$$maxShipRate = stock / minServTime\,, \qquad (2)$$

$$rateShip = MIN\,(maxShipRate;\ rateOrder)\,, \qquad (3)$$

$$d(unsatDemand)/dt = rateUnsatDem\,, \qquad (4)$$

$$rateUnsatDem = max\,(0,\ rateOrder - maxShipRate)\,, \qquad (5)$$

where:

stock - stock reserve amount;

rateProd - the rate of stock replenishment, determined in the production subsystem output;

rateShip - ex-stock delivery rate;

minServTime - minimum lead time, i.e. the period since request is accepted by the sales agent till the product is shipped to the customer (this parameter is independent to the changes in other variables of the system);

maxShipRate - maximum possible shipment rate, which depends on the current stock reserves and minimum lead time;

rateOrder - orders rate; the rate is exogenous to the product stocks and to the order fulfilment subsystem. With introduction of this model into the corporate information system, we are inputting data into the model directly from this system; in this case, the data has been exported from the Excel file;

unsatDemand - unsatisfied demand level;

rateUnsatDem - unsatisfied demand rate.

The considered subsystem enters with the final product input by the production subsystem.

The production subsystem model is demonstrated in Figure 2.

The production process includes a number of stages. Each stage ends with intermediate product output, which

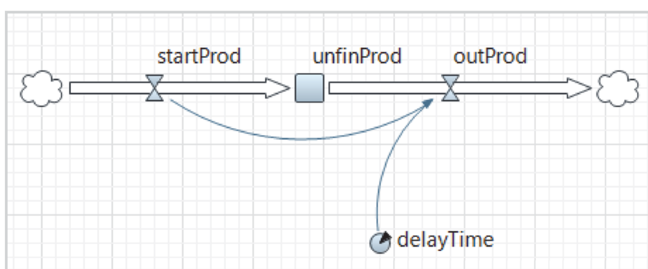

Fig. 2: **Stock and flow diagram of the production subsystem**
Source: Developed by the authors

launch the next stage. To simplify the model, such staging in our case has been regarded through the tertiary delay operator, which depends on technology of the production under analysis.

The model equations are:

$$d(unfinProd) / dt = startProd - outProd, \quad (6)$$

$$outProd = delay3\,(startProd, delayTime). \quad (7)$$

No restrictions are put on production capability and labour forces.

To take coordinated decisions in the supply chain, the models of production and sales subsystems should be combined, as in Figure 3.

The initial rate at the start of production is determined by its optimal value, which, in turn, is predicated by the optimum level of output and adjustments for unfinished goods:

$$startProd = max\,(0, optStartProd), \quad (8)$$

$$optStartProd = optRateProd + corrUnfinProd. \quad (9)$$

Such adjustments are aimed at modifying optimal level of production at the initial stage to keep unfinished production up to the required level. Optimal unfinished production ensures the required output, given the duration of production cycle:

$$corrUnfinProd = (optUnfinProd - unfinProd) / delayTimeCorr, \quad (10)$$

$$optUnfinProd = delayTime * optRateProd. \quad (11)$$

Optimal production output rate is determined by the forecast of orders, with regard to adjustments in finished products stocks. The required output index is positive. We have obtained the following relations:

$$optRateProd = MAX\,(0, predOrder + corrStock), \quad (12)$$

$$corrStock = (optStock - stock) / delayStockCorr, \quad (13)$$

$$optStock = predOrder * (insStock + minTime). \quad (14)$$

Equation (14) is attributed to the fact that to offset unexpected fluctuations in demand or issues with production, the distributor keeps certain buffer stock (insStock) to run uninterrupted product sales. The buffer margin in the model is another exogenous parameter.

The model described by the equations 1 - 14 has an obvious balanced mode - permanent level of demand determines constant value of *startProd*, the system works steadily and does not require adjustments. Minor fluctuations in demand also do not break the system's balance. It is worth to note the way the system is reacting to the sharp upsurges in demand.

To analyse the system's behaviour in this situation, a simulation experiment has been conducted. By simulating a 40% seasonal upsurge, we have stabilized the demand at higher level for certain time lapse. In the system model, the demand increased dramatically, sales coverage ratio (stocks / shipment rate) dropped sharply, ratio between maximum shipment rate and optimal shipment rate changed drastically.

A 40% increase in demand leads to decrease in stocks, but while replenishing them, company still meets 100% of customer demand for some time. Given the production cycle, the rate of final production is still remaining at the same level, thus the chain stocks are further reduced and unsatisfied demand shows up. The gap between actual and optimal stock levels endogenously increases the optimal production rate above the forecasted customer orders, resulting in accelerated growth of unfinished production. The gap between actual and optimal level of unfinished production is growing, thus the desired rate of production is becoming higher than the output. The company's management need some time to adjust to new business situation. Within this period, the system cannot obtain new balance as the demand projection is growing along with the model

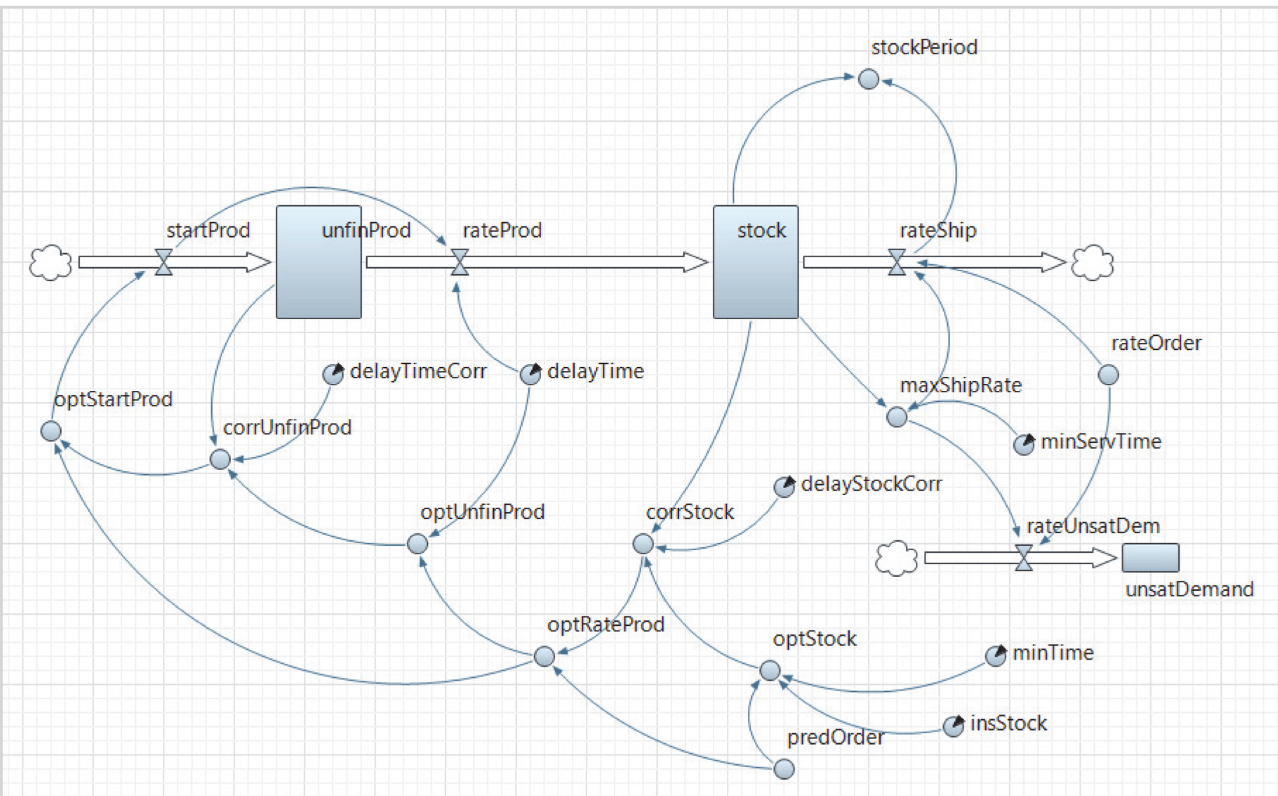

Fig. 3: **Stock and flow diagram of supply chain**
Source: Developed by the authors

value of optimal stock. The gap between actual and optimal stock is widening, causing higher model level of optimal output. The system response exceeds simulated value of the demand upsurge. In our simulation, the system has responded to 40% increase in the demand with 72% increase in the output. At the same time, there has been considerable delays in product delivery. The time gap between the upsurge in demand and maximum output has exceeded the production cycle time two times.

The experiment draws us to the following conclusions. The first response to increased demand is the shrink of stocks due to the delivery delays because of the duration of production cycle. A natural reaction of the company to such sharp reduction in stocks is striving for extreme intensification in reply to the demand upsurge. This causes a multiplicative effect. Since the stocks are initially shrinking, the only way to meet such shortfall is to raise the production rate above the shipments rate. The production shall exceed the shipments rate by sufficiently in volume and time to replenish the stocks in full. The launching peak value should lag behind the moment when the demand increases. The output adjustment reaches maximum at the moment when the stocks reach its minimum. The stocks start to grow only when the output rate exceeds the shipments rate which is always with delay.

The system dynamics model shown above consists of the funds and streams, and explains why the supply chains demonstrate multiplier effects and phase lags. It becomes clear that given the production lag and delays in forecasting, the production rate and production launch rate should exceed and lag behind the demand increase, despite the level of knowledge and qualification of management.

5. Conclusions

While enterprises under review implemented value-oriented approach together with the modern methods of demand forecasting, they witnessed efficiency gains in managerial decisions. Direct outcomes of the approach included reduced fluctuations in inventory, optimization of the value of warehouse stock insurance, and allowed to optimize costs. Based upon the implementation results we may conclude that the system-dynamic model is an adequate tool to uncover interaction of the elements in the supply chain within holding companies, which include both production and distribution network, when demand for their products is the matter of seasonality and high volatility. The authors believe that the value-oriented approach is the most effective one for this type of enterprises.

The application of system dynamics tools in performance forecasting to better address customers and other stakeholders' expectations and needs would allow enterprises to introduce value-oriented approach in management on a long-term balanced basis and to strengthen their competitive advantages.

Further elaboration on system dynamics modelling for empirical assessment of the shared values of customers and other stakeholders include future investigation in the following issues: volume and structure of samples to produce representative results; representation of customers' as well as other stakeholders' satisfaction as a unit of comparative analysis and system dynamics modelling; use of big data in value-oriented approach; definition of acceptable results precision; approach to dissemination of acquired results system dynamics modelling; engagement expansion of the expert community to further examination of the matter.

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