

EVOLUTION OF MAKE-TO-STOCK (MTS) PRODUCTION ENVIRONMENT MANAGEMENT METHODS – RESEARCH CONCEPT

OLGA CIECHAŃSKA

ABSTRACT

The aim of the study is to present a concept for researching the production-for-inventory environment. The article focuses on the comparison of two production stockpiling environments, namely that of Make-to-Stock (MTS) and its developed version, Make-to-Availability (MTA). The article also presents research concepts related to the evolution of the MTS environment.

The article presents the characteristics of production for inventory and for availability, while the matter of maturity models is also presented and a gap in the research is identified. The target and scope of the research is defined and the research program is discussed, and the research methods used at individual research stages have been identified. The status of the level of advancement of the research is presented, as are conclusions from previously undertaken research as well as further directions for this research, recommendations for the future, and the expected results of this work. The synthesis of the research will be to propose a maturity model for organisations functioning in the MTS / MTA environment.

KEY WORDS

Maturity model, Make-to-Stock, Make-to-availability, production environments.

DOI: 10.23762/FSO_VOL6NO2_18_2

OLGA CIECHAŃSKA

e-mail: olga.ciechanska@gmail.com

Warsaw University of Technology,
Poland

Introduction

The challenges which appear in the dynamic environment of modern organisations do not allow them to adopt one long-term strategy of functioning. To maintain and constantly improve market position, it is necessary to constantly adapt to the needs of customers. Many manufacturing enterprises today face the dilemmas of choosing the right manufacturing strategies, which should be flexible and agile,

and which at the same time will not lead to an increase in the costs associated with inventories, but rather will even limit these costs.

In production management, two basic production environments are identified, for which production models have been defined: MTS (Make-To-Stock) and MTO (Make-To-Order) production. The essence of production for stock is delivery to the

customer from inventory and replenishing the level of inventory by supplying products manufactured in accordance with the agreed production schedule. This is different in the case of production to order, in which the order received from the customer determines the characteristics of the product and the time of production.

In companies operating in the FMCG (Fast Moving Customer Goods) sectors, production for stock is currently the dominant model; however, in relation to these enterprises, there is a growing demand for MTA (Make-To-Availability). Generally speaking, this consists of maintaining a level of inventories of finished products in a warehouse, such that the current value is dynamically minimised but the product is available to the customer at any time. This is a relatively new trend in management, as evidenced by the modest amount of literature and the lack of relevant references to scientific research carried out in this area.

In its general assumptions, the postulate of production for availability seems to be attractive to manufacturing companies that strive to maximise results, including the optimisation of inventory levels and leaving their products in a constant state of availability for the customer. This mainly applies to enterprises with mass, large-scale and medium-volume production, producing standardised and unified consumer products which quickly expire or lose their usability, e.g. due to a change in fashion. These include enterprises from such manufacturing industries as food, pharmaceuticals, cosmetics, household chemicals, clothing, small household items, furniture, electronics and household appliances, and so on.

The MTS model has been known for many years and is comprehensively described. There are mathematical models, both deterministic and stochastic, showing how to determine the norms of inven-

tory control in various conditions. The MTA model, however, has not yet been thoroughly tested. It requires a precise description, the definition of production and storage control norms, the construction of a mathematical model and conducting research in various demand and production conditions in order to determine in which conditions the MTA model may have an advantage over MTS. The result will be the definition of transformation processes (transition) from MTS to MTA models, and their systemisation in the form of a maturity model of organisations functioning in the MTS / MTA environments.

1. Theoretical context for solving the research problem

1.1. The essence of MTS / MTA production

The production environment (or production environments) in which the organisation operates is determined by the customer-company relationship. Hill (1996) stated that the production environment defines the company's strategies for the realisation of the product for the client, production methods, and consequently the production model. The factors that determine the nature of the production environment are, among others, the degree of complexity of the supply chain and the preparation of production (construction, technical and documentation).

The basic production environments include (Akincet al. 2012):

- make to stock (MTS),
- make to order (MTO).

The production to stock environment is characterised by Morikawa et al. (2014) and Melnyk and Denzler (1996) who claim that orders for the customer are fulfilled directly from the 'storage shelf'. Production orders are used to supplement stock levels and

are generated when the stock of a given product in the finished goods warehouse reaches the so-called signalling level, or at regular intervals; the delivery quantity is subsequently adjusted to the forecasted intensity of outflow. Determining the norms of inventory control is based on demand forecasts (quantitative forecasting methods). The MTS model is characteristic for stable and reproducible production over time – the mass, high volume, and medium volume production – of unified products. As part of the production for stock environment, its adaptation – MTA – production-to-availability, is appearing more often as a developed approach to production planning.

The term 'production to availability' was introduced by Eliyahu Goldratt, the creator of the Theory of Constraints (TOC). This concept was then developed by Goldratt's associate E. Schragenheim (Schragenheim 2009: 239-264). Production to availability (MTA) is a variation of the production to stock environment MTS, the basic assumption of which is to maintain a level of finished products in the warehouse such that the value is minimal, but characterised by the fact that the product is available to the customer at any time, i.e. located on the storage shelf and available 'on the spot' (Cox and Schleier 2010: 244).

Based on an analysis of the literature, it can be stated that the basic assumptions of MTA are (Ciechańska 2018: 413):

- monitoring the market situation and ensuring that each customer has the possibility of purchasing products;
- daily determination of the quantity and range of products produced, based on current monitoring of product sales – more frequent refreshing of inventories than in MTS;
- maintaining a minimum level of inventory in the warehouse;

- the use of the parameters: 'buffer status' and bottleneck production capacity in order to prioritise production orders;
- treatment of the delivery cycle not as a normative but as a variable whose value depends on the current production capacity of the production department, especially the bottleneck.

The MTS model is characteristic for the FMCG industry, foodstuffs, pharmacy, cosmetics, household chemicals, small household items, furniture, RTV equipment and household appliances. The MTA model includes similar industries with the selection of those in which the key is adherence to timeliness and the suitability for consumption of products, and a guarantee of the usefulness of the product.

The production to stock model has been known and used in enterprises for years (Amaro et al. 1999), and is also widely presented in the literature. There are two classic models of stock control, namely the ordering level model and the ordering cycle model (Bozarth 2006: 331-364). In the first of these, the control codes requiring determination are the batch number and the ordering level (i.e. the level of the inventory indicating the need to immediately issue an order and direct it to the supplier, also known as an emergency supply). In the second, classic model, the appropriate control norms include the ordering cycle and the maximum stock level. Other ordering models are the ordering level model in fixed ordering cycles (monitoring the stock level at fixed time intervals), the minimum-maximum model (permanent ordering cycle, but the order size is dynamic), and the combination of the ordering level model and the fixed ordering cycle (Heizer and Render 2011: 501-525; Hopp and Spearman 2000: 48-108).

The inventory control standards for MTS have been defined and presented in the literature in the form of mathematical models (Christou 2012: 269-331; Harrison and Petty 2002: 195-209). The MTA model is described in the literature in a very general (verbal) way and has not been presented so far in the form of a mathematical model. The graphic presentation of the model in Figure 1 is an original version prepared on the basis of a general description in order to show the nature of production to availability and to compare it with the production to stock model. In the MTA model, unlike MTS, the stock in the warehouse is refreshed more often. The cycle and the volume of delivery are not permanent norms – they are variable – and their value depends directly on the current state of the warehouse and the production capacity available at a given moment (with particular emphasis on the production capacity of the bottleneck).

The graphs show that in the case of MTA, the company is not dealing with an inability to fulfil the client's order on time, while at the same time the minimum (security level) level of stock is violated to a much lesser extent than in the case of MTS and surplus stocks appear less frequently (significant due to the issue of the freezing of capital). The buffer status is a parameter that limits the risk of these two extreme situations. The status of the buffer informs you which percentage of all orders generated are in stock or on the way to the warehouse. Therefore, it protects the company against a lack of availability of the product and prioritises production orders accordingly.

The buffer has been conventionally divided into three zones: green status – inventory level at immediate availability; yellow status – the stock level available 'on the spot', red status – a warning that production to replenish inventory should start immediately. Production orders are gener-

ated at a high frequency (even daily), the size of which depends on the use of inventory in the previous period (day). Production orders do not have a fixed due date. Their degree of urgency is determined by the current status of the buffer: if the current stock level of a given product is in the green or yellow zone, the production order has a priority level of "green" or "yellow", that is, it is queued for execution, but if the buffer penetration is in the red zone, the production order is marked in red and has the highest priority. Establishing order management rules by buffer status is also the expected effect of the research conducted. In addition, despite the same intensity of output of products, the MTA model should not include a situation in which it is impossible to fulfil a delivery to the customer. What is more, it can be observed that the set minimum and maximum reserve levels seem too high in relation to the outflow intensity, and therefore the conclusion may be drawn that a reduction of these norms is necessary to reduce the average cost of inventories. A detailed comparison of the MTS and MTA models is provided in Table 1. The selection of comparative criteria for the production of MTS and MTA is not accidental. The criteria selected for the comparative analysis best show the differences in the models characterised.

Table 1. List of production models for stock and availability according to selected criteria

Criteria \ Model	MTS	MTA
Purpose of the production model	Anticipation of minimum and maximum sales with a specific delivery time with awareness of losses resulting from shortages and surplus stocks	Guaranteeing the delivery of the product to the customer and its availability at such a high level that competitors are unable to match it
Basis for creating production plans	Forecasts and simulations Signal supply (ordering)	Buffer status A resource that limits production capacity
Stock control norms	Defined and described in the literature; they are presented in the form of a mathematical model	Undefined, they need to be described and presented in the form of a mathematical model
Planning time horizon	Aggregate plan (12 months) - rare refreshing of the stock (the refreshing points of the stock result from the planning norms)	Plan update - everyday (1 Day) - more frequent refreshing of the stock (resulting from current consumption and refilling capacity (bottleneck production capacity))
Tools used for planning	Quantitative forecasting methods (projection or causative)	Buffer status Current planned utilisation of production resources, in particular of the bottleneck
The basis for determining the permissible stock level	Historical data Forecasts	Current stock level, buffer status
The basis for starting the order and setting the end date	Warehouse norms: signalling stock, security stock	Per cent of buffer penetration Buffer status Refill time
Main indicators of planning effectiveness	Capacity utilised Productivity	Availability of products
Risk related to planning	Financial losses (the cost of frozen capital in the form of stocks) Not delivering goods on time (production of another assortment)	Non-delivery of goods on time (costs of lost opportunities)
Type of production	Medium serial volume production and high serial volume production, Mass production	Medium serial volume production, high serial volume production

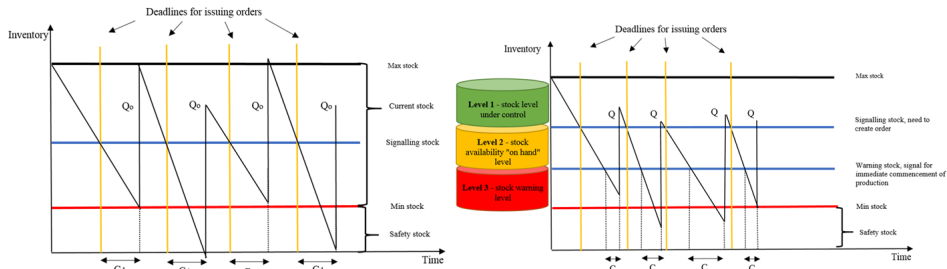
Source: Own elaboration.

The differences between the models will be visible in the value of the objective's function, which consists of two elements:

- cost of maintaining inventories (storage, frozen capital and out-of-date products),
- cost of lost business benefits due to unfulfilled customer orders.

The larger the amount of stock, the higher the cost of maintenance, but the smaller the risk of not meeting the market demand and vice versa. Utilising the MTS and MTA models in regard to different demand scenarios in simulation experiments should affect the value changes of the objective's

function. The issue of simulation modelling as one of the research methods will be discussed later in the paper.

Figure 1. Comparison of the MTS and MTA production environment models**Legend:**

Min stock – minimal stock, Max stock – maximum stock

C_d , C – delivery cycle, Q_o , Q – batch size

Source: Own elaboration.

All the norms in Figure 1 in the MTA model (minimum, maximum, signalling, warning) were charted in a conventional way to show the differences between MTS and MTA. In fact, they should be designated in a different way than with MTS. Defining the basic concepts and norms of the MTA model and the methods of their determination are some of the expected results of the doctoral dissertation. Determining the norms and defining the concepts for the MTA environment will be made possible by the simulation of the mathematical model proposed in the work. Conclusions from the experiments conducted in the simulation model will serve to build a maturity model containing the best practices for organisations that want to effectively and efficiently implement the MTS / MTA model.

1.2. The essence of maturity models in management

The maturity model is a set of various tools and practices that enable the assessment of the organisation's competencies in the field of management as well as the improvement of key factors leading to the achievement of the assumed goals (Van Looy 214: 5). The maturation of the organisation means a systematic improvement of its skills as well as the processes implemented within, in order to achieve higher

productivity at a given time (Hammer 2007). Organising knowledge of the maturation of an organisation was reflected in the models of maturity. The main assumptions for the use of maturity models are:

- measuring the progress achieved by the organisation through continuous improvement in various areas of management;
- the implementation of strictly defined stages of the model (levels of maturity) in order to achieve effects concerning key factors in the organisation;
- achieving further levels of maturity, which allows the organisation to improve applied practices, starting from practices and processes that are undefined and inconsistent, through repetitive practices at the level of organisational cells, then comprehensively defined business processes (predictable and statistically managed), to the continuous process of innovation and optimisation (Kosieradzka and Smagowicz 2016: 282).

1.3. Identification of the research gap and justification of the topic

From the description of the theoretical context which constitutes the descriptions of the MTS / MTA environment and maturity

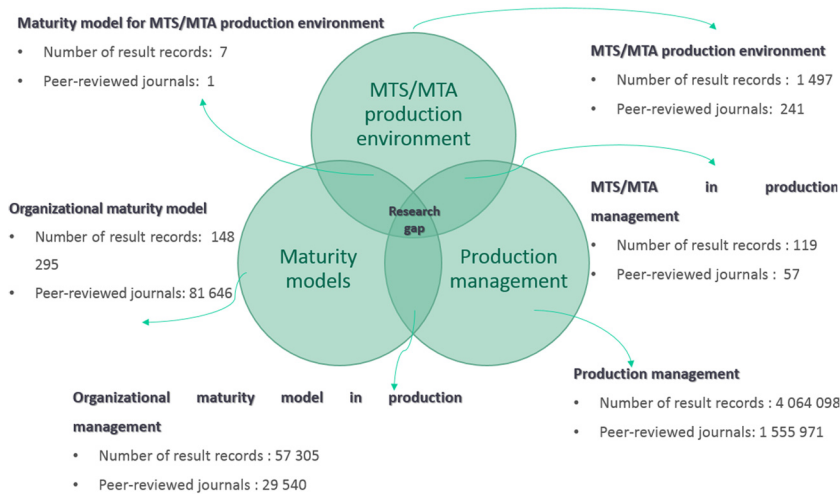
models for the undertaken research problems, it appears that it is located at the interface of three areas:

- MTS / MTA production environments,
- production management,
- organisational maturity models.

Figure 2 shows the current state of knowledge in the scope of the indicated

subject. There is little information on the MTA production environment in literature sources. The amount of available information only allows for the description of the general outline of the functioning of this model in the organisation.

Figure 2. Results of studies of the literature - identification of the research gap



Source: Own elaboration.

In analysing the literature, it was determined that there is a lack of scientific publications and common knowledge of research results on the subject of production for accessibility, which makes this issue attractive in the context of the undertaken research. It is expected that the impact of the MTA approach on production management may involve the need to adequately define production control standards, as well as verify the possibility of developing a new approach to determining the key performance indicators of the organisation and selecting the best production management practices.

The themes of maturity models are gaining importance through the increasing number of publications on – and the growing interest of researchers in – this

trend, because they are a kind of “recipe for success” for organisations that wish to develop and improve their processes in an efficient and effective way. The synthetic approach to the results of the research conducted will be the maturity model for organisations operating in the MTS / MTA environment as a tool facilitating the gradual transformation of the MTS system into a MTA system.

2. Objective of the work and research questions

Literature studies carried out so far, as well as case studies, indicate the need to:

- develop and organise terminology related to the production model for accessibility (MTA);

- develop standards for the MTA production and Key Performance Indicators (KPIs);
- make comparisons of MTS and MTA models (analysis and assessment of environments - defining the principles of the functioning of the MTA model, describing the behaviour of models depending on input data, determining what criteria and conditions minimise the previously described objective's function and maximise the availability indicator, indicating the advantages and disadvantages of models for experimental scenarios of storage levels and intensity of demand, and the identification of good practices for MTS and MTA);
- structure and supplement the repository of good practices for manufacturing enterprises operating in the MTS / MTA environment,
- develop the MTS / MTA maturity model.

The needs identified determine the main research objective (CG - main goal):

CG: Development of a maturity model for organisations operating in the MTS / MTA production environment.

The research subject is the production for availability environment as a developed form of the production to stock environment, and changes related to the transformation of the MTS environment into a MTA environment. Both production environments will be tested under the same external (market demand) and internal (structure of the production system) conditions. The research will be carried out based on experiments in a simulation program on models for the MTS and MTA environments. The differences between the models will be reflected in the values of the inventory control standards and the method of inventory replenishment. Scenarios of demand intensity for both models will be prepared, which will check the response of the environments to exter-

nal conditions and the method of stocking. The observed output variables will be the objective's function constituting the sum of costs related to maintaining stocks and lost profits due to unfulfilled customer orders and the product availability indicator.

The subject of the research will be a company operating in the MTS environment determined by a series of attributes enabling the generalisation of the model of its functioning.

The purpose, subject and object of the research defined in this way translate into the following specific research objectives (CS – specific objective):

CS1: Defining the production environment for availability (MTA)

CS2: Comparison of the functioning of MTS and MTA models in various conditions (internal and external) and obtaining an answer to the question of whether the MTA model produces better results than the MTS model in all conditions

CS3: Identify the best production management practices for MTS / MTA

CS4: To build a maturity model for organisations using MTS / MTA

CS5: Determine the transformation process from the MTS environment to the MTA based on the maturity model.

The implementation of the goals set in this way will enable researchers to obtain answers to the following research questions (PB – research question):

PB1: Is the MTA model better than MTS in all conditions due to the adopted objective's function?

PB2: How to set production control standards for the MTA environment?

PB 3: What are the best production practices that enable production for availability?

PB4: What are the next steps to transform the MTS environment into the MTA environment?

The research program is presented in Table 2.

Table 2. Research program with assigned research methods

Work stages	Objectives	Research methods
1. Review of issues regarding the specificity of production for availability	• Analysis and evaluation of the MTS environment (principles, advantages, disadvantages) • Defining the terms of production for availability MTA • Identification of production management methods that enable production for availability	Analysis of source literature Analysis of descriptions of case studies
2. Review of applied maturity models in production management	• Systematisation of knowledge in the field of maturity models • Identification of process or subject areas used in models • Identification of good practices • Review of the applied maturity grades	Analysis of source literature
3. Compare the MTS and MTA models	• Defining the requirements and assumptions for the development of a mathematical (simulation) model • Construction and validation of the simulation model • Definition of scenarios and input data for the simulation program • Conducting simulation experiments on MTS and MTA models • Simulation verification based on a case study • Analysis and evaluation of the MTS / MTA environment (principles, advantages, disadvantages) based on the conducted simulations	Analytical modelling Simulation modelling Simulation experiments Case studies
4. Developing the maturity model of organisations operating in the MTS / MTA environment	• Formulating the assumptions and requirements of the maturity model • Identification of "good practices" in the field of production management • Analysis and development of production control rules and operating rules for the MTA environment based on the simulations conducted • Implementation of conclusions from the simulations carried out on the maturity model • The maturity model of organisations operating in the MTS / MTA environment • Development of a good practice repository • Verified and completed maturity model that can be used in a production company	Analysis of literature research results Analysis of experimental results in a simulation program Inductive inference Verification of the maturity model
5. Using the maturity model to determine transformation paths from MTS to MTA	• Determining the transformation paths of the MTS production environment to MTA using the maturity model	Case studies Simulation modelling Inductive inference

Source: Own elaboration.

Conclusions

The literature studies carried out so far in the area of maturity models, production environments and production management identify a research gap at the point at which they intersect, clearly confirming the feasibility and validity of further research in this area. Currently the literature analyses are in their final stage: systematising the terms of production for availability and maturity models. Based on the analysis of available literature and case study descriptions, methods of production management characteristic to production for availability (MTA) have been identified. The analytical

models of production for stock and availability have been compared, which will enable the definition of requirements and assumptions as well as the construction of simulation models of the MTS and MTA production environments. On this basis, simulation models will be prepared in the next stage of work.

The next steps are the preparation of scenarios and input data for the simulation program, simulation experiments that will be verified using a case study, and ultimately a detailed comparative analysis and evaluation of the MTS / MTA environment

(setting rules, indication of the advantages and disadvantages of models), as well as a detailed description of standards of production and inventory control and supplementing the set of good management practices used in these environments.

The results of simulation experiments and the classification of good practices will serve to formulate assumptions and requirements as well as to build a model for the maturity of organisations operating in the MTS / MTA environment. The maturity model for the MTS / MTA production environments will include identified areas relevant to these production environments, a repository of good practices and defined levels of maturity, the achievement of which is conditioned by the implementation of appropriate practices in the organisation. The final stage of the work will be to identify the transformation paths of the MTS production environment to MTA using the maturity model developed in the fourth stage.

References

- Akinc, U., Jack, R. Meredith (2012), Make-to-forecast: Customisation with fast delivery, *International Journal of Operations & Production Management*, 35(5): 728-750.
- Amaro, G., Hendry, L., Kingsman, B. (1999), Competitive advantage, customisation and a new taxonomy for non-make-to-stock companies, *International Journal of Operations & Production Management*, 19(4): 349-371.
- Bozarth, C., Handfield, R.B. (2006), *Introduction to operations and supply chain management*, New Jersey: Pearson Education M.U.A.
- Christou, I.T. (2012), *Quantitative methods in supply chain management. Models and Algorithms*, London: Springer Verlag.
- Ciechańska, O. (2018), Model wytwarzania na dostępność jako nowe podejście do planowania produkcji, in: R. Knosala (Ed.), *Innowacje w zarządzaniu i inżynierii produkcji*, V.I. (pp. 410-419), Opole: Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją.
- Cox, J.F., Schleier, J.G. (2010), *Theory of constraints handbook*, New York: McGraw Hill.
- Hammer, M. (2007), The process audit, *Harvard Business Review*, 85(4): 111-113.
- Harrison, D.K., Petty, D.J. (2002), *Systems for planning and control in manufacturing*, Oxford: IIE Core Textbooks Series.
- Heizer, J., Render, B., (2011), *Operations management*, Boston: Pearson.
- Hill, T. (1994), *Manufacturing strategy: Text and cases*, Business One Irwin.
- Hopp, W.J., Spearman, M.L. (2000), *Factory physics*, Boston: Irwin-McGraw-Hill.
- Kosieradzka, A., Smagowicz, J. (2016), Analiza porównawcza modeli dojrzałości organizacji, in: M. Ćwiklicki, M. Jabłoński, S. Mazur (Eds.), *Współczesne koncepcje zarządzania publicznego. Wyzwania modernizacyjne sektora publicznego* (pp. 280-293), Kraków: Fundacja Gospodarki i Administracji Publicznej.
- Lockyer, K., Muhlemann, A., Oakland, J.S. (1992), *Production and operation management*, London: Pitman.
- Melnik S.A., Denzler D.R. (1996), *Operations management. A value-driven approach*, Chicago: Irwin.
- Morikawa K., Takahashi K., Hirotani D. (2014), Make-to-stock policies for a multistage serial system under a make-to-order production environment, *International Journal of Production Economics*, 147: 30-37.
- Schrageheim, E., Dettmer, H.W., Patterson, J. (2009), *Supply chain management at Warp Speed*, Boca Raton: Taylor & Francis.
- Van Looy, A. (2014), A comparative study on a sample of business process maturity models, *Business Process Maturity*, Heidelberg-New York: Springer International Publishing.

Olga Ciechańska is a PhD student at the Chair of Innovation and Entrepreneurship at the Faculty of Management at the Warsaw University of Technology (Poland). She specialises in theoretical and practical issues relating to production management. She is the author of several scientific papers on maturity models, introducing changes and improvements in production processes, make-to-stock and make-to-availability strategies published in both Polish and international journals. She has earned M.Sc. and Eng. degrees in Management and Production Engineering from the Warsaw University of Technology. Additionally, she is working on her PhD thesis, the topic of which is the maturity model of organisations operating in the MTS / MTA production environment. Currently she combines her scientific activity with her position as a production engineer at a large industrial automation company.