Flexible and scalable production logistics for technology-oriented start-ups

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Abstract

Technology-oriented start-ups often consider problems of production logistics in a late development phase, when a lot of money, capacity and manpower have already been spent on special processes or inefficient material provisions. However, this can be prevented if aspects of production logistics are considered at an early stage. But existing concepts are often not usable for start-ups. These concepts are mostly designed for a steady state of production and require a long familiarization. Therefore this paper presents a flexible and scalable concept for the production logistics of technology-oriented start-ups, which grows with them and is especially tailored to their requirements.

Keywords: production logistics, production planning, entrepreneurship

Introduction

Technology-oriented start-ups are young companies which are usually founded with a low seed capital (Alisch *et al.*, 2004) and pursue the goal of bringing an innovative product to the market. They often focus on product development and financing aspects, especially in the beginning. Cross-cutting functions like production logistics are not given much attention and are often considered in a late development phase, when a lot of money, capacity and manpower have already been spent on special processes or inefficient material provisions.

Additionally start-ups have a high growth potential and a high growth rate (Kollmann *et al.*, 2015). Therefore, their requirements in the field of production logistics also change very fast without being recognised. For example the sales quantity increases mostly very fast during the development. Because of this increase start-ups has to adapt the batch size and provision quantity. But start-ups do not react on this increase timely and notice the inefficient batch size and provision quantity tardy. Moreover, recommendations for start-ups on how to plan and design flexible and scalable production logistics effectively do not exist. Therefore, the aim of this research is to develop start-up-specific recommendations to overcome the challenges of production logistics. The result is a flexible and scalable concept for the production logistics, which is specifically tailored to

the requirements of technology-oriented start-ups. Within this research production logistics is defined as a functional area of manufacturing companies, which "plans, controls and monitors the material flow from the raw material warehouse of the procurement over the steps of the manufacturing process up to the finished products warehouse." (Pawellek, 2004)

The paper is organised as follows: in the next chapter a literature review on existing approaches for production logistics for established companies and on recommendations for start-ups is presented. These review will point out that the existing concepts are not suitable for start-ups. Therefore a development model for technology-oriented start-ups is shown. This model represents the basis for designing a start-up-specific concept for production logistics and defines the development stages, which are used to allocate the challenges of the production logistics of technology-oriented start-ups. Next, methods to solve the challenges of production logistics are derived. The paper is summarised in the last chapter and finished with an outlook of future research.

Literature Review

At first it is necessary to conduct a literature review on existing approaches for established companies for solving the challenges of production logistics and to discuss them with regard to the requirements of technology-oriented start-ups. By means of this discussion should be highlighted if the existing approaches are usable for technology-oriented start-ups. The literature review revealed two common approaches for established companies which are introduced and discussed in the next section.

The first approach is Lean Logistics, which is developed from Lean Management. Lean Logistics defines guidelines for designing a logistics concept based on the objectives of lean management (Pfeifer and Weiss, 1994). The approach focuses on the alignment of logistics to customer requirements and the integration of the pull principle. For this purpose, guidelines, methods and tools are shown in order to design a concept for production logistics for the company itself (Günthner *et al.*, 2013). The guidelines and targets described can be used in part for start-ups. For example, the robustness of processes or the pursuit of perfection is also a target which is important for a young company. However, the goals of long-term and flow orientation are not relevant in an early development stage of the company when only a small number of products are produced. Furthermore, tools and methods from Lean Logistics can only be used partly. The methods always assume a steady state of production. Additionally, they can only be useful integrated when a high number of products were produced (Günthner *et al.*, 2013). Special solutions for small-scale productions are not found in the literature. Thus, the sole usage of the Lean Logistics approach is not useful to design the production logistics from the very beginning in a flexible and scalable way.

The second approach is Production Planning and Control, which is needed to fulfil the orders from the market. That means suppling the products in the required quantity and in the agreed time (Schmidt, 2008). Within the Production Planning and Control, the following functions are necessary: production programme planning, quantity planning, scheduling and operative capacity planning, order request and order controlling (Schulte, 2017). In the literature there are a lot of methods for soling each of these functions. But not every method is applicable for technology-oriented start-ups. For example the program-oriented methods to define the batch-size can only be used when the company knows exactly how much products they will sale in future. But because of the uncertainties and the fast increase of sales quantities this method is not suitable for start-

ups. That shows that a start-up has to find the best method out of all these methods, which is very time-consuming. Thus, Production Planning and Control is not easy to implement.

The discussion of these two approaches shows that they are not useful for technology-oriented start-ups holistic. Rather they should use a combination of different methods of these approaches to solve the challenges of production logistics in an easy way and to design their production logistics in a flexible and scalable way. Due to the fact that start-ups focus on product development and financing aspects and that the founders and employees often have a low competence in logistics issues, the concept has to be easy to implement. But as it is described above especially the approach of Production Planning and Control is very time-consuming and not easy to implement. An other fact is that the concept has to be flexible, scalable and should be able to grow with a start-up to prevent that changes in the requirements will not be recognised early on. But the presented approaches assume a steady state of production, which is not given by start-ups.

After the discussion of existing approaches for the production logistics of established companies a second literature review on existing approaches for start-ups take place. The literature review revealed that the market for start-up guidelines includes a large number of websites (e.g. Allis, 2018; Menlo Media UG, 2018; startups.co, 2018), literature (e.g. Blank, 2013; Deeb, 2013; Ries, 2011) and software tools (e.g. Google LLC, 2018; StartupResources.io, 2018; Startup Stash, 2018). But these guidelines focus on marketing, e-commerce, business planning, finance, funding, law, taxes, controlling, corporate management and human resources management. Guidelines, methods or software support for production logistics do not exist. In addition, most of the available literature does not focus on issues of technology-oriented start-ups. The only concept tailored to technology-oriented start-ups can be found in the book *The Lean Startup* (Ries, 2011). However, it only concentrates on strategic decisions in the areas of business development, personnel planning and financing. There are no concrete recommendations to support operational tasks like production planning at an early stage of development.

Development Model of technology-oriented start-ups

As described in the literature review, a start-up-specific concept to design the production logistics flexible and scalable is needed. This can be reached with a development model for technology-oriented start-ups. This model defines the development stages, which are used to allocate the challenges of production logistics. Consequently, as long as a start-up knows which stage it is currently in, it can derive which of these challenges to consider in their current development. Therefore, the model includes qualitative indicators. In this paper the phase model of Hietschold and Fottner (2018) is used. This model is developed especially for technology-oriented start-ups and considers their requirements. It combines the business development models of Ripsas and Tröger (2014), Blank (2013) and Schefczyk (2006) with the product development model of Cooper (1996). The model is shown in Figure 1.

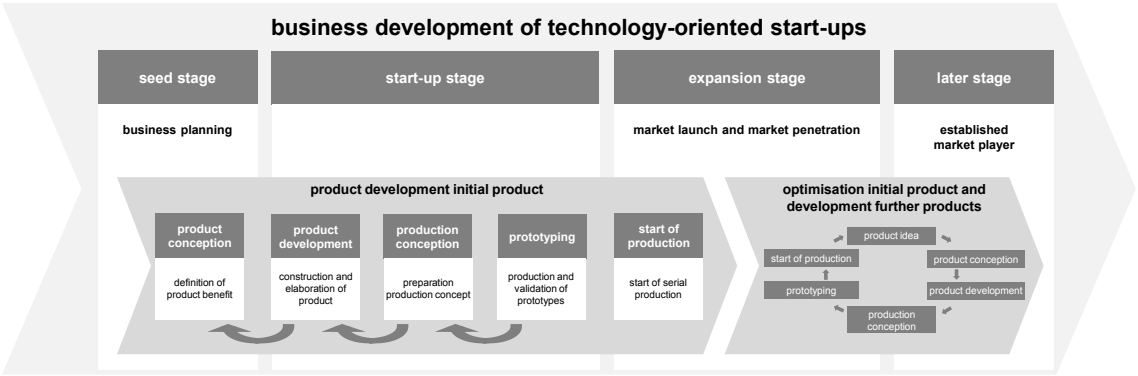

Figure 1 - Development model of technology-oriented start-ups, based on Hietschold and Fottner (2018)

Each phase of this model is described with indicators to help start-ups to allocate in one development phase. The indicators and their manifestations in each phase are shown in Figure 2.

BUSINESS DEVELOPMENT		seed stage	start-up stage			expansion stage	later stage
PRODUCT DEVELOPMENT		product conception	product development	production conception	prototyping	start of production	optimisation initial product and development further products
INDICATOR	**sales / customer benefits**	no sales	realisation fo first sales and/or cutomer benefits			strong sales and/or customer growth	stable sales
	marketing and sales activities	first market anaysis, first customer contacts	development of a marketing and sales concept			intensive marketing efforts, expansion of the sales system	
	market uncertainty	very high	high			low	hardly noticeable
	technology readiness level	basic and technology research, formulationg the technical concept, technical feasibility studies	analytical and experimental evidence of critical functions, experimental setup in the laboratory and in the operational environment			prodcut launch and operations	qualified product, evidently successfully used in the marked
	role of founder	personal handling of all activities	assuption of operational as well as strategic activities			assumption of strategic activities only	delegation of strategic activities
	standardisation	no processes exist, operations manly take place for the first time	identification, standardisation and formalisation of processes			establishing standard processes	optimisation of standard processes, high efficiency of core processes
	organisational structures	no organisational structure exist	generating of first organisational structures and hierarchy levels			building of departments	permanent organisational structures

Figure 2 – Indicators to allocate in one development phase, based on Hietschold and Fottner (2018)

So that start-ups get to know which challenges of production logistics are currently relevant, the challenges have to be allocated to the phases in which they come up. For this purpose, a literature review on challenges of established companies was conducted first which revealed a lot of challenges. Afterwards, an online survey on technology-oriented start-ups was conducted in order to identify the relevant challenges for technology-oriented start-ups and to highlight in which development phase the challenges come up. Taking the literature review and the survey into consideration, the development model was complemented by the challenges of production logistics (Figure 3). The challenges do not occur temporarily in one stage but come up for the first time either with the prototyping in the start-up stage or with the start of production in the expansion stage. Subsequently they are performed at regular intervals in the expansion and later stage.

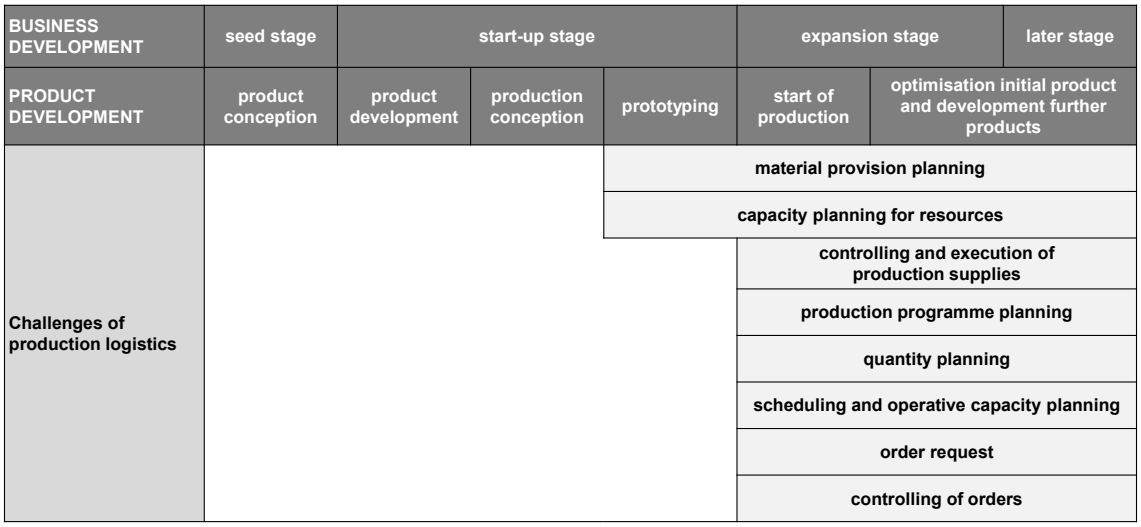

Figure 3 – Allocation of challenges of production logistics to the development stages

Methods for solving the production logistics of technology-oriented start-ups

In order that start-ups can solve the identified challenges of production logistics, start-up-specific methods were developed. For this purpose, a detailed literature review on existing methods for established companies was conducted. The identified solutions are evaluated for transferability to the requirements of start-ups and adjusted if necessary. For the evaluation the requirements of technology-oriented start-ups were used as they are presented in the literature review (easy to implement, flexible, scalable, grow with a start-up).

In order to ensure an easy implementation, only data, which is available to start-ups should be considered during the evaluation of the existing solutions. For using the solutions only the existing data should be necessary. To identify which data are available for start-ups from the very beginning, interviews with technology-oriented start-ups and start-up consultants were conducted. The result is that start-ups have already prepared sales and financial plans in the context of business planning (seed stage), but these are still very vague and can change during their further development. This situation leads to the result that these data can be used for solving the challenges, but the solutions should also be monitored with this data periodically. The existing data which is necessary especially for the production logistics are the sales plan and the production type. The sales plan defines how many products will be produced per year and the production type defines in which way the products will be produced. (e.g. single-item production, series production, shop floor production, flow production, make to order, make to stock).

After the requirements were set, the solutions could be evaluated and the most suitable solutions for start-ups could be identified. In addition, each solution is described in the form of a profile which contains the following information:

- Planning level
- Development phase
- Responsible person
- Frequency
- Necessary data
- Necessary solutions of other challenges
- Result

In the next sections the identified solutions were described shortly for each challenge and the profiles were presented.

Material provision planning

The task of material provision is to deliver the material to the production at the right time and location as well as in the required type and quantity. The planning of material supply includes the following steps: definition of suitable provision principles, the organisational design of the necessary logistical processes such as transport, transshipment and storage measures as well as the technical design of the provisioning and information flow system (Bullinger and Lung, 1994). For solving the material provision planning, start-ups can use the method from Bullinger and Lung (1994). He describes in an easy way how the steps of the material provision planning can be done and what should be considered.

Profile:

- Planning level: strategic
- Development phase: from start-up stage (prototyping)
- Responsible person: supply chain manager and production manager
- Frequency: annual or when the production process changes or when the sales plan changes significantly
- Necessary data: production type, sales plan, bill of material, production process (including production steps, necessary material, equipment, process time)
- Solutions of other challenges: none
- Result: provision principle, technical design of the provision, flow of information principle, amount of provided material per workstation and per material

Capacity planning for resources

The capacity planning for the resources is used to determine the needed capacity that is required for each resource to fulfil the sales orders. The needed capacity is determined by the required productions steps in the individual periods. For solving the capacity planning for the resources, start-ups can use the method from Schuh *et al.* (2012). Within this method start-ups can calculate the needed capacity by multiplying the job times of each production step with the quantities. The result is the needed processing for each production step.

Profile:

- Planning level: strategic
- Development phase: from start-up stage (prototyping)
- Responsible person: production manager
- Frequency: annual or when the production process changes or when the sales plan changes significantly
- Necessary data: production type, sales plan, production process (including production steps, necessary material, equipment, process time)
- Solutions of other challenges: none
- Result: necessary amount of equipment which is necessary to fulfil customer orders.

Controlling and execution of production supplies
The controlling of production supplies includes all tasks which are necessary to monitor and ensure the material supply, from the initiation of the provision order to the notification of the completed provisioning process. These includes demand determination, scheduling and capacity planning as well as inventory management (Bullinger and Lung, 1994; Nyhuis *et al.*, 2012). The execution of production supplies includes all necessary physical processes such as picking, transporting and handling at the workplace for the provision of materials in production (Nyhuis *et al.*, 2012). For solving the controlling and execution of production supplies, start-ups can use the method from Nyhuis *et al.* (2012). He describes in an easy way how the physical processes of the material provision can be done and what should be considered.

Profile:

- Planning level: operative
- Development phase: from expansion stage
- Responsible person: supply chain manager and production manager
- Frequency: daily
- Necessary data: production type, sales plan, bill of material
- Solutions of other challenges: material provision planning
- Result: There is constantly sufficient material available in the production to fulfil customer orders

Production programme planning
With the aid of production programme planning, the quantities of products which have to be produced are defined for the future time periods. The basis is the sales plan, which is designed in coordination between procurement, production and sales. This sales plan leads to a feasible production programme. In addition to the assessments of the market development and the strategic goals of the start-up, the restrictions of production (e.g. production capacities) and of procurement (e.g. material supply) have to be considered (Schmidt, 2008). For solving the production programme planning, start-ups can use the heuristic demand determination from Schmidt (2008). This method is especially suitable for start-ups because the production program is defined by means of sales estimates.

Profile:

- Planning level: operative
- Development phase: from expansion stage
- Responsible person: supply chain manager, production manager and sales manager
- Frequency: each month
- Necessary data: production type, sales plan, bill of material, production process (including production steps, necessary material, equipment, process time)
- Solutions of other challenges: material provision planning
- Result: feasible production programme

Quantity planning
Within the quantity planning, the production programme is used to determine at what time and in what quantity an order has to be produced. For this purpose the optimal batch-size is determined for each period (Schmidt, 2008). For determining the batch-size, start-ups can use the dynamic batch-size formula from Recker (2002). This method adopts the

classical batch-size formula to a dynamic sales quantity. Therefore this method is especially suitable for start-ups.

Profile:

- Planning level: operative
- Development phase: from expansion stage
- Responsible person: production manager
- Frequency: each month
- Necessary data: production type, sales plan, bill of material
- Solutions of other challenges: production programme planning
- Result: optimal batch-size per period and product

Scheduling and operative capacity planning

The subject matter of scheduling and operative capacity planning is the scheduling of orders which are created in the quantity planning. This is generally a multi-level planning with increasing accuracy (rough, medium and detailed planning) (Schmidt, 2008). For solving the Scheduling and operative capacity planning, start-ups can use the method from Schmidt (2008).

Profile:

- Planning level: operative
- Development phase: from expansion stage
- Responsible person: production manager
- Frequency: each month
- Necessary data: production type, sales plan, bill of material, production process (including production steps, necessary material, equipment, process time)
- Solutions of other challenges: production programme planning, quantity planning
- Result: Scheduling of the orders from the programme and quantity planning

Order request

The order request includes the preparation of production orders from the production programme as well as the release of the orders and their integration into the production process. It also determines the sequence in which the orders are processed (Nebl, 2007). For solving the order request, start-ups can use the method from Nebl (2007), which is adopted a little bit. In the method are defined the following steps which are necessary to request an order: sequencing of orders, request of production orders, management of order backlog, drawing up and dispensing the working documents, allocation of production orders to the several capacity units and availability check for capacities. For sequencing the orders propose Nebl (2007) the priority rules from Neidhardt (2007). These are instructions which helps to determine the sequence in which orders placed in front of a machine are proceeded. This priority rules can also be used by start-ups.

Profile:

- Planning level: operative
- Development phase: from expansion stage
- Responsible person: production manager
- Frequency: daily

- Necessary data: production type, sales plan, bill of material, production process (including production steps, necessary material, equipment, process time)
- Solutions of other challenges: production programme planning, quantity planning, scheduling and operative capacity planning
- Result: Approved production orders and their processing sequence, order documents (also digital)

Controlling of orders

The controlling of orders is used to determine the actual production process. By comparing the actual with the planned production process, any deviations that occur can be identified and measures can be taken to safeguard the order (Nebl, 2007). For realising the controlling of orders, start-ups can use the method from Nebl (2007). He defines the following information which should be given to the planning department in order to compare the actual with the planned production process: time of completion, needed time and effort for rework if necessary.

Profile:

- Planning level: operative
- Development phase: from expansion stage
- Responsible person: production manager
- Frequency: daily
- Necessary data: production type, sales plan, bill of material, production process (including production steps, necessary material, equipment, process time)
- Solutions of other challenges: production programme planning, quantity planning, scheduling and operative capacity planning, order request
- Result: target-actual comparison of the production process, measures for securing orders in case of deviations

Conclusion

The aim of this research was to develop start-up-specific recommendations to overcome the challenges of production logistics. With these recommendations start-ups should be able to design flexible and scalable production logistics easily and early on. For this purpose the development model from Hietschold and Fottner (2018) was used. This model defines the development stages, which were used to allocate the challenges of the production logistics of technology-oriented start-ups. For the identified challenges, start-up-specific methods were developed and described in the form of profiles. Thus, technology-oriented start-ups are supported in the development and optimisation of a concept for the production logistics which is tailored to their requirements.

In future a validation of the developed concept with several technology-oriented start-ups will take place. For this purpose an example start-up will be designed. Based on this, start-ups should solve the challenges with the suggested methods.

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References

Alisch, K., Arentzen, U. and Winter, E. (2004), *Gabler Wirtschaftslexikon,* Gabler, Wiesbaden.

Allis, R. (2018), "The Startup Guide", available at: http://startupguide.com/ (accessed 27 April 2018).

Bereuter, F. (2012), *Internet Startup - Chancen und Risiken einer Unternehmensgründung im Internet*, Diplomica Verlag, Hamburg.

Blank, S. (2013), *The four steps to the epiphany: Successful strategies for products that win,* K & S Ranch, Pescadero.

Bullinger, H.-J. and Lung, M.M. (1994), *Planung der Materialberteitstellung in der Montage*, Springer Fachmedien, Wiesbaden.

Cooper, R.G. (1996), "Overhauling the new product process", *Industrial Marketing Management*, Vol. 25 No. 6, pp. 465–482.

Deeb, G. (2013), *101 Startup Lessons: An entrepreneur's Handbook*, Blog Into Book.

Google LLC (2018), "Tools für dein neues Startup", available at: https://startup.google.com/ (accessed 27 April 2018).

Günthner, W.A., Durchholz, J., Klenk, E. and Boppert, J. (2013), *Schlanke Logistikprozesse: Handbuch für den Planer*, Springer Vieweg, Berlin Heidelberg.

Hietschold, N. and Fottner, J. (2018), "Beschaffung bei technologieorientierten Startups. Wie Startups beschaffungslogistische Aspekte von Beginn an berücksichtigen können", *ZWF*, Vol. 113 No. 1-2, pp. 31-36.

Kollmann, T., Stöckmann, C., Linstaedt, J. and Kensbock, J. (2015), *European Startup Monitor 2015*, Universität Duisburg-Essen, Department of Economics and Business Administration, E-Business and E-Entrepreneurship Research Group, Essen.

Menlo Media UG (2018), "EU-Startups", available at: http://www.eu-startups.com/ (accessed 27 April 2018).

Nebl, T. (2007), *Produktionswirtschaft,* Oldenbourg, München.

Neidhardt, U. (2007), "Einsatz von Prioritätsregeln zur Erreichung ökonomischer Zielstellungen", Dissertation, Institut für Produktionswirtschaft, Universität Rostock, Aachen.

Nyhuis, P., Weindahl, H.-P. and Wagner, C. (2012), "Materialbereitstellung in der Montage", in Lotter, B. and Wiendahl, H.-P. (Eds.), *Montage in der industriellen Produktion: Ein Handbuch für die Praxis*, *VDI-Buch*, 2. Aufl. 2012, Springer Vieweg, Berlin, Heidelberg, pp. 285–313.

Pawellek, G. (2004), "Produktionslogistik", in Klaus, P. and Krieger, W. (Eds.), Gabler Lexikon Logistik, Gabler Verlag, Wiesbaden, pp. 458–463.

Pfeifer, W. and Weiss, E. (1994), *Lean Management: Grundlagen der Führung und Organisation lernender Unternehmen*, Erich Schmidt Verlag, Berlin.

Recker, A. (2002), *Loßgrößenplanung in PPS-Systemen: Optimierende versus heuristische Verfahren*, Gabler, Wiesbaden.

Ries, E. (2011), *The lean startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses*, Crown Business, New York, N.Y.

Ripsas, S. and Tröger, S. (2014), *Deutscher Startup Monitor 2014*, KPMG in Deutschland, Berlin.

Schefczyk, M. (2006), *Finanzieren mit Venture Capital und Private Equity: Grundlagen für Investoren, Finanzintermediäre, Unternehmer und Wissenschaftler, EBL-Schweitzer,* 2. Aufl., Schäffer-Poeschel, Stuttgart.

Schmidt, M. (2008), "Produktionsplanung und -steuerung", in Arnold, D., Isermann, H., Kuhn, A., Tempelmeier, H. and Furmans, K. (Eds.), *Handbuch Logistik*, Springer, Berlin, Heidelberg, pp. 323–370.

Schuh, G., Brandenburg, U. and Cuber, S. (2012), "Aufgaben", in Schuh, G. and Stich, V. (Eds.), *Produktionsplanung und -steuerung 1: Grundlagen der PPS*, Springer Vieweg, Berlin Heidelberg, pp. 29–81.

Schulte, C. (2017), *Logistik: Wege zur Optimierung der Supply Chain*, Franz Vahlen, München.

Startup Stash (2018), "STARTUPSTASH", available at: http://startupstash.com/ (accessed 27 April 2018).

StartupResources.io (2018), "Startup Resources", available at: http://startupresources.io/ (accessed 27 April 2018).

startups.co (2018), "startups.co", available at: https://www.startups.co/ (accessed 27 April 2018).