CHEMICAL ENGINEERING TRANSACTIONS

VOL. 76, 2019

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Petar S. Varbanov, Timothy G. Walmsley, Jiří J. Klemeš, Panos Seferlis

ISBN 978-88-95608-73-0; **ISSN** 2283-9216

DOI: 10.3303/CET1976083

Graphical Pinch Analysis Approach to Cash Flow Management in Engineering Project

Jason Maximino C. Ongpeng[a,*], Kathleen B. Aviso[b], Dominic C. Y. Foo[c], Raymond R. Tan[b]

[a]Civil Engineering Department, De La Salle University, 2401 Taft Avenue, 0922 Manila, Philippines
[b]Chemical Engineering Department, De La Salle University, 2401 Taft Avenue, 0922 Manila, Philippines
[c]Department of Chemical and Environmental Engineering, University of Nottingham Malaysia, Broga Road, 43500 Semenyih, Selangor, Malaysia
jason.ongpeng@dlsu.edu.ph

Pinch Analysis (PA) methodology was originally developed for determining feasible Heat Integration targets in process plants, and for designing optimal Heat Exchanger Networks to achieve the previously determined energy budget. This powerful methodology has since been extended to a wide range of applications, such as Mass Integration, Carbon Management and Financial PA. All these extensions have the common feature of utilizing a stream quality index that defines direction of flow, in the same way that temperature differences determine heat transfer. In this paper, a graphical PA approach to cash flow analysis and management in engineering projects is proposed in ensuring project sustainability. This method considers the positive and negative cash flows that occur over time in an engineering project. A case study is used to illustrate how this approach can provide insights for managers to synchronize the operations of a single project to stay within the firm's cash flow limits. Such strategies can potentially affect the sustainability of construction projects. There were three solutions considered in the case study. Based on the results, it was found that from the hypothetical example, the ideal solution is to allot 50 % or 75 % of the total inflow assigned to labour outflow with a pinch period of 1 month. It resulted in a minimum loan value 61.2 %-months for materials outflow.

1. Introduction

Proper financial management is essential to ensure the profitability and sustainability of engineering projects. Many engineering contractors are small and medium enterprises (SME) which are at risk of bankruptcy from the mishandling of financial accounts. On the other hand, SME contractors' success can be achieved by maximizing profit, minimizing expenses, and efficiently utilizing funds for the cash flow expenditures throughout the project duration. Effective decision support techniques can improve the management of engineering projects and thus enhance profitability of the SMEs.

Project finance is one of the strategies in sustainability and it serves as one of the cores and support activities within project-based firms (Aarseth et al., 2017). Investigation on the relationship of project sustainability and project management showed that financial and economic performance while taking care of compliance issues and ethics is important in a company (Martens and Carvalho, 2017). In addition, sustainability on supply chain finance have focused on optimal financing strategies and improvements in the supply chain efficiency using different payment terms (Zhan et al., 2018). Thus, the importance of project sustainability and project management through proper financial management is deemed important where tools in engineering projects should be developed to aid decision makers in attaining sustainable growth.

To aid sustainability in an engineering project, a graphical methodology based on Pinch Analysis (PA) is developed. The methodology deals with the funds made available to the project from various sources such as down payment (DP), progress billings (PB), and investor's fund. In addition, expenses such as labour and material costs are taken into account. PA is one of the major methodologies used in Process Integration (PI). It was originally developed for the design of Heat Exchanger Networks to minimize energy consumption in process plants (Linnhoff and Flower, 1978). The methodology has been extended based on structural similarities of

Paper Received: 30/03/2019; Revised: 27/05/2019; Accepted: 30/05/2019
Please cite this article as: Ongpeng J.M.C., Aviso K.B., Foo D.C.Y., Tan R.R., 2019, Graphical Pinch Analysis Approach to Cash Flow Management in Engineering Project, Chemical Engineering Transactions, 76, 493-498 DOI:10.3303/CET1976083

different applications; for example, heat and mass transfer analogies led to the development of the PA approach for the synthesis of Mass Exchange Network (El-Halwagi and Manousiothakis, 1989), as well as other Mass Integration domains such as water and hydrogen integration (Foo, 2012). In both cases, PA methodology relies on establishing an optimal system target for minimum consumption of a valuable external resource (e.g., steam or fresh solvent), coupled with optimal allocation of streams based on quantity (e.g., enthalpy or mass flowrate) and quality (e.g., temperature and concentration) constraints. Principles underlying PA allow it to be used for many problems that require similar allocation of streams based on quantity and quality (Tan et al., 2015); the methodology can be implemented using various graphical or algebraic techniques that are mathematically equivalent (Bandyopadhyay, 2015). Although it requires the use of simplifying assumptions in many of these applications, PA is still regarded as a valuable complement to Mathematical Programming (MP) models that are also used in PI problems (Klemeš and Kravanja, 2013). Both PA and MP approaches to PI are now incorporated in modern textbooks dedicated to process design (Smith, 2016) and resource conservation (Foo, 2012). Many key developments in PI methodology development and industrial applications are summarized in a handbook (Klemeš, 2013), while a more recent review article gives a comprehensive survey of a wide range of PA applications and extensions (Klemeš et al., 2018).

Since the beginning of the century, PA methodologies have been extended to handle various production planning problems. The seminal work on production supply chain management was reported by Singhvi and Shenoy (2002), where graphical PA technique was developed to target optimum production rate for an aggregate planning problem. Chaturvedi and Bandyopadhyay (2015) later extended the work for various energy supply chain problems. Later works on production planning were reported for the scheduling of batch process equipment (Foo et al., 2007) and human resource (Foo et al., 2010). Another important extension in this aspect is the use of PA for financial resource management. The latter was first proposed by Zhelev (2005) where graphical tools were developed to evaluate projects of different investments and savings. Subsequent work by Bandyopadhyay et al. (2016) proposed a graphical PA method to allocate fund based on Return on Investment (ROI) considerations. This methodology was then extended and applied to the selection of energy conservation projects (Roychaudhuri et al., 2017), as well as environmental management projects (Roychaudhuri and Bandyopadhyay, 2018). Financial considerations have also been incorporated into planning power generation mix in India (Bandyopadhyay and Desai, 2016).

Few articles dealt with cash flow management in construction. Purnus and Bordea (2016) examined the use of multi-criteria cash flow analysis in providing client and contractor practical tool for decision making. Huang et al. (2013) proposed cash flow based credit model for prequalification of contractors, while Chandrashekhar Iyer et al. (2016) proposed cash flow forecasting model that integrates schedule delays and cost escalations on multiple projects. In this paper, a graphical financial PA methodology is developed to deal specifically with cash flow problems encountered in engineering projects where labour and materials component are separated to assess proper financial options in maximizing resources. In the case of SMEs, the timing of cash flows may become problematic, resulting in the need to resort to external financing or other measures such as renegotiation of payment terms with suppliers. This can be facilitated effectively through the graphical PA method as described in the next section. A construction project case study is then solved to illustrate its usefulness. Conclusions and prospects for future work are then discussed.

2. Problem statement

The known parameters in the proposed method are total inflow, total outflow, materials outflow, labour outflow, and period of the construction project. The objective is to optimize outflow by paying the labour outflow on time or propose labour payment contract agreement for subcontractor, and to minimize the loan value for materials outflow in percentage-months using PA. The percentage-months in the discussion refers to the product of the loan value in percent and duration of loan in months. The prioritization of funds for labour over materials is to make sure that the employees have budget for their safety, security, and daily expenditures. Lastly, the unknown parameters are loan values for labour transaction before pinch, pinch period for labour payment contract agreement, and materials transaction loan value after pinch that can help decision makers in attaining successful and sustainable engineering project.

3. Methodology

The cash flow is considered as either an inflow or an outflow. The inflow at a particular period may be smaller, equal to, or larger than the outflow at a given period. The analysis of data for any given circumstance is crucial in the financial management of a project. For example, if the inflow is smaller than the outflow at a particular period, then management may opt to secure a loan from the bank or financial institution during that period. Since construction projects are very complex, the outflow is divided into two, namely the labour outflow and the materials outflow. The rule of thumb for a successful construction project is to prioritize outflow by paying the needed obligations (e.g. labour expenses), to improve labour payment contract agreement for subcontractor, and to minimize the loanable amount in paying other obligations (e.g. material supplies).

The graphical PA procedure makes use of two composite curves for each labour and material transaction. The first composite curve, named here after as financial composite curve (FCC), plots the time period in the y-axis and the cumulative financial inflows or outflows on the x-axis. The second composite curve on the other hand, named here after as financial grand composite curve (FGCC), plots the time period in the y-axis and the difference between the inflows and outflows (e.g. loan values) on the x-axis. Similar to common PA, the proposed methodology uses metrics of quality and quantity. The quality metric or the driving force is the time of the project, while the quantity metric is defined as the cash flow and the difference between inflows and outflows. The composite curves FCC and FGCC considered the use of step line graph to show the start and end of each period.

The proposed PA methodology is as follows:

Step 1. Tabulate the total inflow and total outflow with respect to the duration of the project. Separate the total outflow into two components: labour outflow and materials outflow. This distribution depends on the available data for estimating the labour and the material cost. In this PA method, the percentage of labour inflow allocation to pay labour outflow is made as a parameter. This is assumed by decision makers.

Step 2. Plot the labour FCC with the period on the y-axis and the labour inflow and outflow on the x-axis as labour cost transaction. Shift the entire labour outflow FCC upwards until it stays above or equal to the labour inflow FCC entirely. The intersection of the two composite curves, labour inflow FCC and shifted labour outflow FCC, is the pinch point.

Step 3. Plot the labour FGCC with the period on the y-axis and the labour cost difference on the x-axis.

Step 4. Plot the material FCC with the period on the y-axis and material budget inflow and material outflow on the x-axis as material cost transaction. The material budget inflow is the sum of material inflow and the surplus from labour transactions after pinch (from Step 3).

Step 5. Plot the material FGCC with the period on the y-axis and the material cost difference on the x-axis.

Step 6. Assume different combination of parameters on allocating labour inflow and materials inflow. Repeat steps 1 to 5 to generate loan values.

Step 7. After having different combinations of labour inflow and outflow, graph the results of the loan value for each combination showing the loan value for labour and materials.

These steps are applied to an illustrative example in the next section.

4. Case study

A hypothetical project is illustrated in this section shown in Table 1. The inflows considered were down payment and progress billings. All measurements were normalized as percentages of the total monetary value of the project. All monetary inflows and outflows with respect to each month made excluded Profit and Overhead (P&O) before tax. The analysed data in this paper does not include the P&O before tax of the contractor to prevent bias since P&O before tax is different from one project to another, mainly due to management strategy.

Table 1: Hypothetical data used for the case study in percentage

Duration (months)	Total Inflow	Total Outflow	Labour Outflow	Materials Outflow	Labour Inflow	Materials Inflow
0	10	30	9	21	7.5	2.5
1	20	48	14.4	33.6	15	5
2	42	65	19.5	45.5	31.5	10.5
3	70	82	24.6	57.4	52.5	17.5
4	89	96	28.8	67.2	66.75	22.25
5	100	100	30	70	75	25

The first three columns of Table 1 show the duration, total inflow, and total outflow of the example project. Three solutions were made: 1.) assign 50 % of total inflow to fund labour, 2.) assign 75 % of total inflow to fund labour, 3.) assign 100 % of total inflow to fund labour. The total outflow shown in column 3 was subdivided into labour outflow and materials outflow set as 30 % and 70 % of the total outflow, respectively. For illustration, Table 1 column 6 represents the solution for assigning 75 % of total inflow to fund labour, while remaining 25 % of total inflow to fund materials as seen in Table 1 column 7. The labour FCC is plotted in Figure 1 and is shifted upwards by one period, called labour outflow pinch. The labour FGCC is generated as shown in Figure 2. Without pinch, the loan value is 1.5 %-months to guarantee that labour cost is paid. With the pinch of 1 month, the loan value is eliminated, and surplus is generated. The pinch of 1-month period represents a delay in payment of labour outflow. This is achieved by proposing a 1-month payment terms for labour supply agreement from subcontractor. The surplus generated after pinch was added to material inflow, Table 1 column 7, and resulted to material budget inflow. Likewise, for material transaction, Figure 3 is generated showing the material FCC. Lastly, Figure 4 showing the material FGCC is plotted that resulted to a loan value of 61.2 %-months shown in the shaded area along negative x-axis. This ends the first solution assigning 75 % of total inflow to fund labour. Two solutions, assigning 50 % and 100 % of total inflow to fund labour, are added by repeating steps from the proposed PA method seen in the previous section.

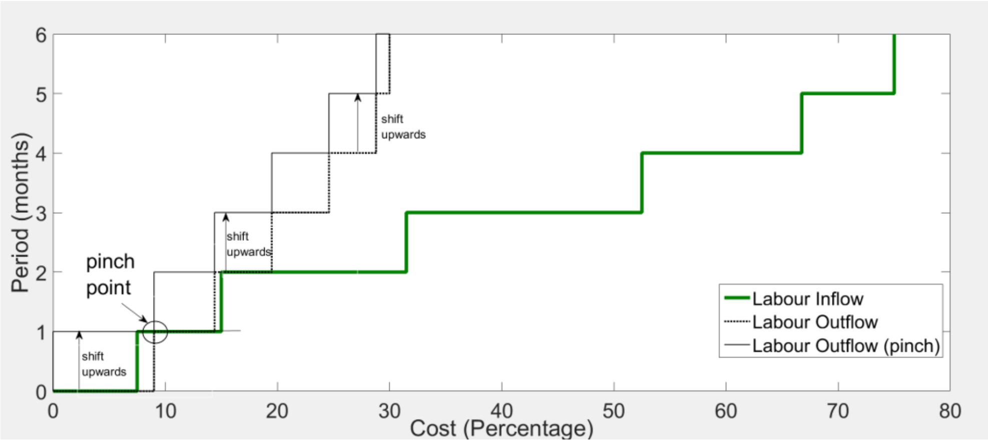

Figure 1: Labour FCC

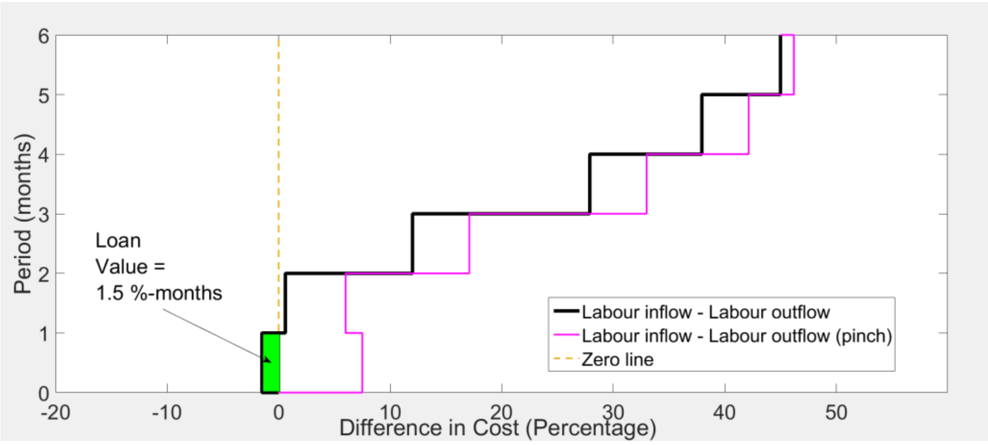

Figure 2: Labour FGCC

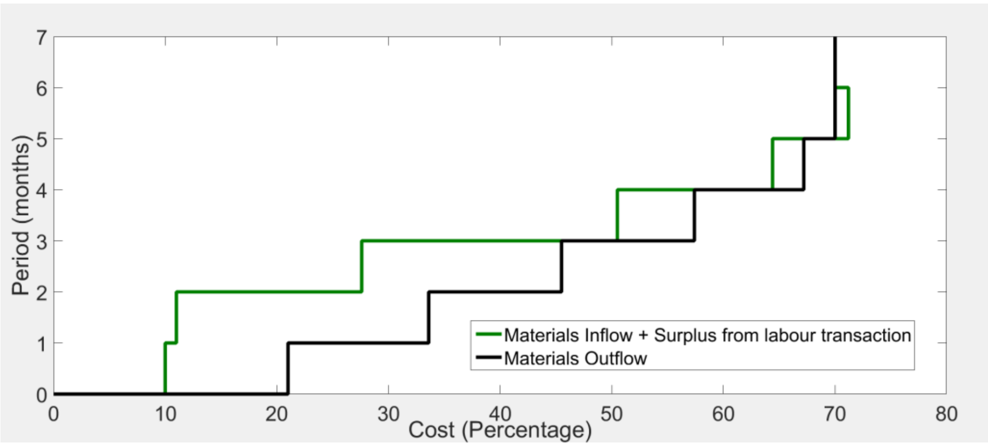

Figure 3: Material FCC

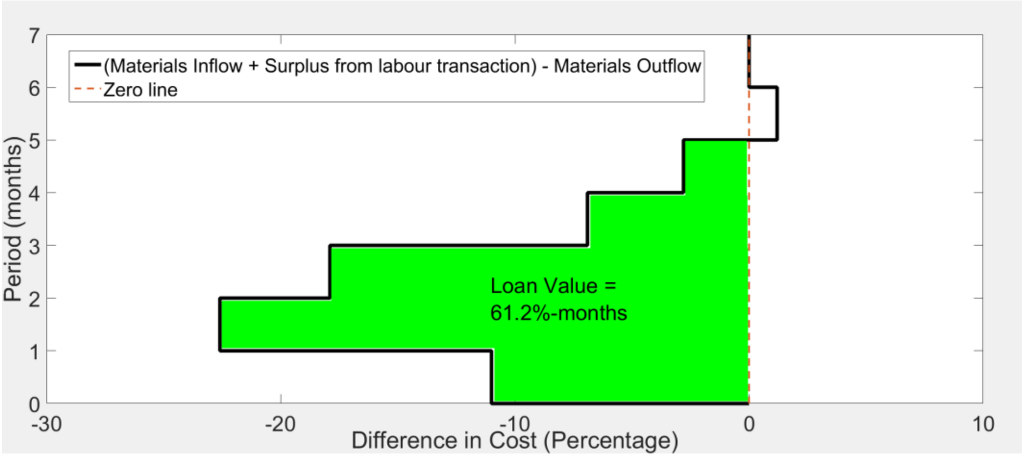

Figure 4: Material FGCC

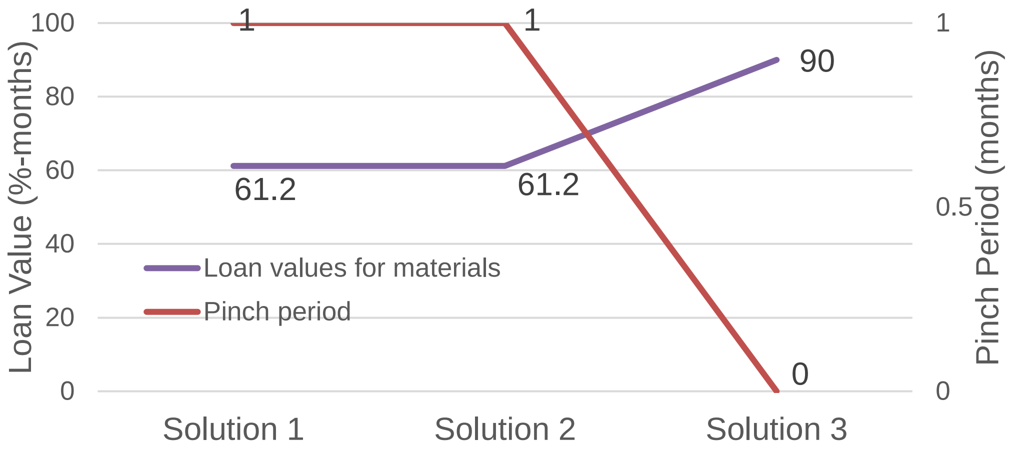

Figure 5: Loan values for materials and pinch period after PA

From the proposed PA methodology, a case study with three solutions were attained. These solutions comprise of labour inflow allocation of 50 %, 75 %, and 100 % of the total inflow to fund labour, respectively. It was found out that based from Figure 5, the best solution is the assignment of 50 % or 75 % of total inflow to fund labour with a pinch of 1 month, while the loan values for materials is 61.2 %-months. This proposed PA can aid decision makers on how to allocate properly the finances and to propose subcontractor payment terms contract agreement to aid project sustainability.

5. Conclusions

A graphical PA approach for financial management in engineering projects has been developed. The method ensures that the obligations of the engineering contractor to the workers and suppliers are met with minimal need for supplementary financing. The method proposed here uses PA principles to optimize allocation of funds, and also provides a visual tool for effective communication to aid decision-making. A construction project case study was solved to illustrate this approach. In the future, extensions can deal with financial cash flow of multiple projects to further increase the scope of applicability of financial PA and to integrate other factors which affect the sustainability of construction projects. Different loan sources of varying payment terms, lending interest rates, and present value to supplement the financial requirements can be considered. Optimum solutions without iteration can be developed using automated targeting model for future works.

References

Aarseth W., Ahola T., Aaltonen K., Okland A., Andersen B., 2017, Project sustainability strategies: A systematic literature review, International Journal of Project Management, 35, 1071-1083.

Bandyopadhyay S., 2015, Mathematical foundation of Pinch Analysis, Chemical Engineering Transactions, 45, 1753–1758.
Bandyopadhyay S., Desai N.B., 2016, Cost optimal energy sector planning: a Pinch Analysis approach, Journal of Cleaner Production, 136, 246–253.
Bandyopadhyay S., Foo D.C.Y., Tan R.R., 2016, Feeling the Pinch? Chemical Engineering Progress, 112, 46–49.
Chandrashekr Iyer K., Kumar R., 2016, Impact of delay and escalation on cash flow and profitability in a real estate project, Procedia Engineering, 145, 388-395.
Chaturvedi, N.D. and Bandyopadhyay, S. 2015, Targeting Aggregate Production Planning for an Energy Supply Chain. Industrial & Engineering Chemistry Research, 54, 6941−6949.
El-Halwagi M.M., Manousiouthakis V., 1989, Synthesis of Mass Exchange Networks, AIChE Journal, 35, 1233–1244.
Foo D.C.Y., 2012, Process Integration for Resource Conservation, CRC Press, Boca Raton, FL, USA.
Foo D.C.Y., Hallale N., Tan R.R., 2007, Pinch Analysis approach to short-term scheduling of batch reactors in multi-purpose plants, International Journal of Chemical Reactor Engineering, 5, A94.
Foo D.C.Y., Hallale N., Tan R.R., 2010, Optimize shift scheduling using Pinch Analysis, Chemical Engineering, 117, 48–52.
Huang W.H., Tserng H.P., Liao H.H., Yin, S.Y.L., Chen P.C., Lei M.C., 2013, Contractor financial prequalification using simulation method based on cash flow model, Automation in Construction, 35, 254-262.
Klemeš J.J. (Ed), 2013, Handbook of Process Integration (PI): Minimisation of Energy and Water Use, Waste and Emissions, Woodhead Publishing Limited/Elsevier, Cambridge, UK.
Klemeš J.J., Kravanja Z., 2013, Forty years of Heat Integration: Pinch Analysis (PA) and Mathematical Programming (MP), Current Opinion in Chemical Engineering, 2, 461–474.
Klemeš J.J., Varbanov P.S., Walmsley T.G., Jia X., 2018, New directions in the implementation of Pinch Methodology (PM), Renewable and Sustainable Energy Reviews, 98, 439–468.
Linnhoff B., Flower J.R., 1978, Synthesis of Heat Exchanger Networks, AIChE Journal, 24, 633–654.
Purnus A., Bodea C.N., 2016, Mult-criteria cash flow analysis in construction projects, Procedia Engineering, 164, 98-105.
Martens M.L., Carvalho M., 2017. Key factors of sustainability in project management context: A survey exploring the project manager’s perspective, International Journal of Project Management, 35, 1084-1102.
Roychaudhuri P.S., Kazantzi V., Foo D.C.Y., Tan R.R., Bandyopadhyay S., 2017, Selection of energy conservation projects through Financial Pinch Analysis, Energy, 138, 602–615.
Roychaudhuri P.S., Bandyopadhyay S., 2018, Financial Pinch Analysis: Minimum opportunity cost targeting algorithm, Journal of Environmental Management, 212, 88–98.
Singhvi A., Shenoy U.V., 2002, Aggregate planning in supply chains by Pinch Analysis, Chemical Engineering Research and Design, 80, 597–605.
Smith R., 2016, Chemical Process Design and Integration, 2nd ed., Wiley, Cambridge, UK.
Tan R.R., Bandyopadhyay S., Foo D.C.Y., Ng D.K.S., 2015, Prospects for novel Pinch Analysis application domains in the 21st Century, Chemical Engineering Transactions, 45, 1741–1746.
Zhan J., Li S., Chen X., 2018. The impact of financing mechanism on supply chain sustainability and efficiency, Journal of Cleaner Production, 205, 407-418.
Zhelev T.K., 2005, On the integrated management of industrial resources incorporating finances, Journal of Cleaner Production, 13, 469–474.