sciendo

DOI: 10.2478/rjti-2023-0008

ROMANIAN JOURNAL
OF TRANSPORT INFRASTRUCTURE

THE CONCEPT AND ALGORITHMIC METHOD OF OPTIMIZING THE „IN SITU" ASPHALT RECYCLING PROCESSES

Oana Tonciu, Facultatea Inginerie Mecanică și Robotică în Construcții, Universitatea Tehnică de Construcții București, oana.tonciu@utcb.ro , tel: 0740953645;
Ioan – Mihail Savaniu, Facultatea Inginerie Mecanică și Robotică în Construcții, Universitatea Tehnică de Construcții București
Catalin Francu, Facultatea Inginerie Mecanică și Robotică în Construcții, Universitatea Tehnică de Construcții București, catalin.francu@utcb.ro
Ștefan Mocanu, Facultatea Inginerie Mecanică și Robotică în Construcții, Universitatea Tehnică de Construcții București, mocanustef@gmail.com

Rezumat

Lucrarea prezintă rezultatul cercetărilor privind alegerea variantelor de mecanizare a proceselor tehnologice pe baza criteriilor de costuri efective și energie operațională.

Pe baza teoriei grafurilor este concepută metoda de selectare a variantei de mecanizare care să ducă la atingerea unor indicatori tehnico-economici predictibili. Astfel, etapa de selectare constituie punctul de plecare pentru procesele tehnologice și echipamentele operaționale de execuție în frontul de lucru. În acest caz, reciclarea la rece in situ poate fi optimizată prin costuri și puteri de acționare la valori minime.

Graful propus are ca elemente principale nodurile prin care sunt reprezentate procesele tehnologice simple asociate cu variantele de utilaje folosite.

Fiecare nod al grafului conține următoarele informații referitoare la tipul utilajului, mărimea de intrare/ieșire, algoritmul de evaluare și decizie.

În final, se prezintă un studiu de caz pentru sistemul tehnologic de reciclare cu echipamente Wirtgen.

Cuvinte cheie: reciclare, asfalt, selectare, mecanizare, costuri

Abstract

The paper presents the result of research on choosing of options for technological equipments, processus based on the criteria of effective costs and operational energy.

Based on graph theory, the method of selecting the mechanization variant is designed to achieve predictable technical and economic indicators. Thus, the selection stage is the starting point for the technological processes and operational equipment of execution on the working front. In this case, in-situ cold recycling can be optimized with minimal costs and operating power.

The proposed graph has as main elements the nodes through which the simple technological processes associated with the variants of the technological equipments used are represented.

Each node of the graph contains the following information regarding the machine type, input/output size, evaluation and decision algorithm.

Finally, a case study for the Wirtgen equipment recycling technology system is presented.

Keywords: recycling, asphalt, selection, mechanization, costs.

1. INTRODUCTION

Road system rehabilitation works involve a wide variety of technical and technological solutions.

Selecting technological equipments that will lead to the achievement of high-performance technical and economic indicators becomes the essential issue that decides both the technological processing variant and the typology of technological equipment. A first research direction in the field was focused on the operating behavior of equipment and their reliability [1,2,3,4]. Obviously, the productivity of the equipment was also an important aspect taken into account [5, 6,7].

Consequently, the identification and structuring of technological processes for the execution of road systems rehabilitation can generate different solutions, depending on the factors of influence (type of works, nature of materials, local location conditions, mechanization variants) [8, 9, 10, 11,12,13,14].

2. OPERATIONAL CONCEPT OF EXECUTION OF WORKS "IN SITU"

The concept of in situ recycling mechanization works is based on the following steps:

- setting the value M^{ij} of the optimization parameters on simple process variants;
- summation of parameter values, by simple process variants, for the components of complex technological processes;
- optimal analysis of the cumulative parameter value $M^{j} = \sum_{i=1}^{n_j} M^{ij} (UM)$
- the cumulative parameter M^{j} corresponds to the complex technological process variant j, and n_j is the number of simple technological processes components of the complex process variant j;

- finally select the effective value variant (minimum or maximum, as appropriate)
- establishing the final variant based on the optimization decision according to the technical-economic requirement of the technological process "in situ"

The graph, used as a mathematical tool for the purpose of selection, has as its basic elements the nodes by which the simple technological processes associated with the variants of the machines used are represented. The technological association, on variants of complex processes of them, is made by horizontal arrows. The graph also contains two fictitious activities: START and FINISH. These knots will have no machine type and parameter sizes will all be zero.

3. ALGORITHM OF THE IN SITU TECHNOLOGICAL PROCESS

The analysis algorithm with graph theory is designed with the following informational structure:

- the technological equipment type;
- the input value M_I^i of the node, obtained by taking over the minimum value from the previous activities, with which the analyzed activity is in direct technological relation;
- own value M_P^i represented by the cumulative value established for the analyzed activity;
- output value or carried over value M_R^i ; it is obtained by summing the input value with the successive values of the parameter until the iteration is completed.

The determination of the efficient (minimum or maximum) value of the parameter (economic or technical) is made by following steps:

- identification of mechanization variants for each simple process;
- drawing the graph that modelling the variants of complex processes obtained through the technological association of the activities and types of equipment;
- calculation of own values for each activity and variant of the type of technological equipment and their registration on the graph;
- calculation of the input and output values, going through the graph from the initial node to the final node, resulting in the efficient cumulative value of the parameter sought;
- identification of the complex process variant that ensures the efficient cumulative value;
- to perform the last operation, the graph from the final node to the initial node is run on the path formed by arrows that unite the carry-over and entry equal

values, between two adjacent activities. To highlight this path, the arrows will be drawn with a bold, doubled or differently colored line [4].

4. CASE STUDY. OPTIMIZATION OF THE TECHNOLOGICAL PROCESS "IN SITU" WITH HIGH PERFORMANCE TECHNOLOGICAL EQUIPMENT

Based on the method of determining the value of a parameter, in general, the size of any other parameter which is important, in this case, costs and power requirements shall be determined similarly.

Thus, for the complex model variants of cold recycling "in situ" (figure 1), the operating costs and the power requirements were determined, and the variant for which these values are minimal, will be optimal and effectively applicable.

In this case, for the application in which the cost of operation is determined, in the case of complex rehabilitation processes with cold, in situ recycling of asphalt materials, the following associations are made (figure 1):

- the input value M_I^i of the node is replaced by the input cost C_I^i obtained by taking over the minimum cost carried over by the previous activities with which the analyzed activity is in direct technological relationship. Thus, the equation can be written $C_I^i = \min\left(C_R^{i-1}\right)$

- the own value M_P^i is replaced by the own cost C_P^i represented by the operating cost established for the activity reviewed $C_P^i = C_C^{ij}$, in which C_C^{ij} is the cumulative cost corresponding to the simple process i within the complex technological process variant j

- the output value or the carried over value M_R^i is replaced by the exit cost or the carried over cost C_R^i, which is obtained by adding the entry costs to the own cost: $C_R^i = C_I^i + C_P^i$

To simplify the representation, the two fictitious nodes contain a single value, i.e. zero for the initial node and C_C the final node. The application based on actual operating costs for complex model variants structured in Figure 1 is shown in Figure 2.

For the application in which the minimum power requirement was determined (Figure 3), the following associations were considered:

- the input value M_I^i of the node is replaced by the input power P_I^i obtained by taking over the minimum power carried over by the previous activities, with

which the analyzed activity is in direct technological relation; thus, the equation can be written $P_I^i = \min\left(P_R^{i-1}\right)$

- its own value M_P^i is replaced by its own installed power P_P^i ;

- the output value or carried over value M_R^i shall be replaced by the output power or carried over power P_R^i which is obtained by adding the input power to its own power $P_R^i = P_I^i + P_P^i$

The working algorithm, in this case, in Figure 3, is similar to that used in the application in Figure 2.

The applications presented took into account the usual types of recyclers produced by Wirtgen[15] whose main technical characteristics are given in Table 1.

Table 1. Characteristics of the recyclers

Characteristics of the recycler	**UM**	**2200 CR**	**WR 2000**	**WR 2400**	**WR 2500**	**WR 4200**
Working width	mm	2200	2000	2438	2438	2800 - 4200
Milling depth	mm	0 – 350	-	-	-	-
Depth of recycling	mm	0 - 250	0 - 500	0- 500	0 - 500	300
Engine power	KW (CP)	671 (913)	314 (428)	500 (680)	500 (680)	2 x 433 (2x589)
Weight of equipment	daN	46200	22900	32000	36500	77000

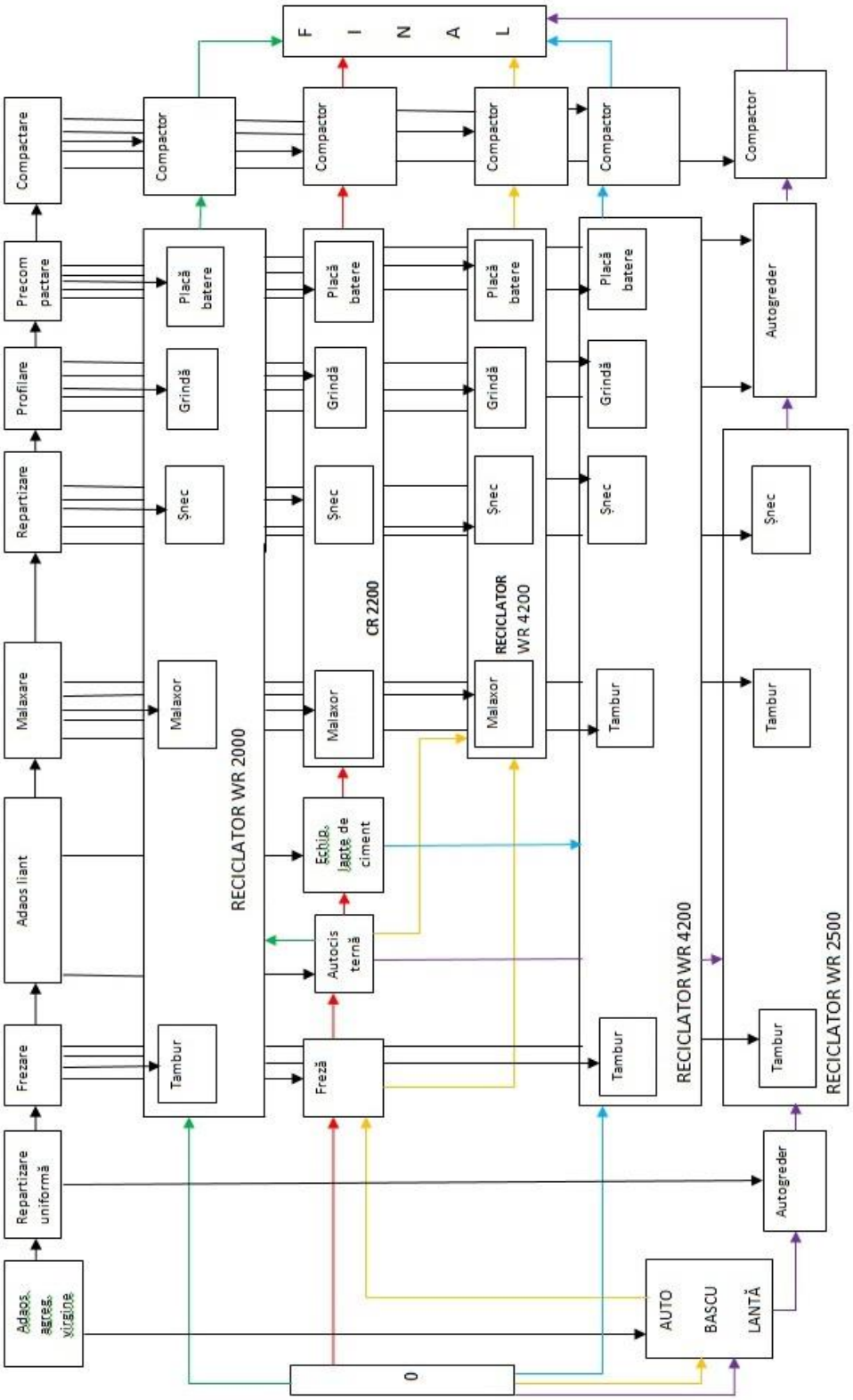


Figure 1. Variants of modeling the complex rehabilitation process with cold recycling

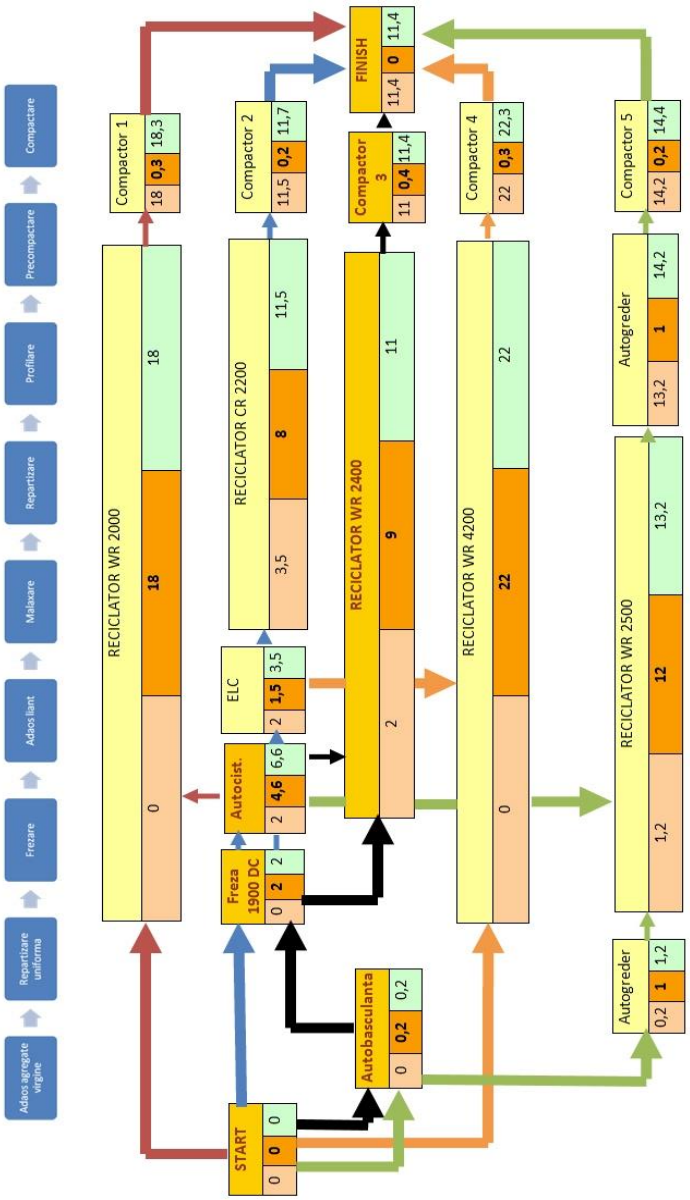


Figure 2. Graph for establishing the technological mechanization solution having as a criterion the real operating cost

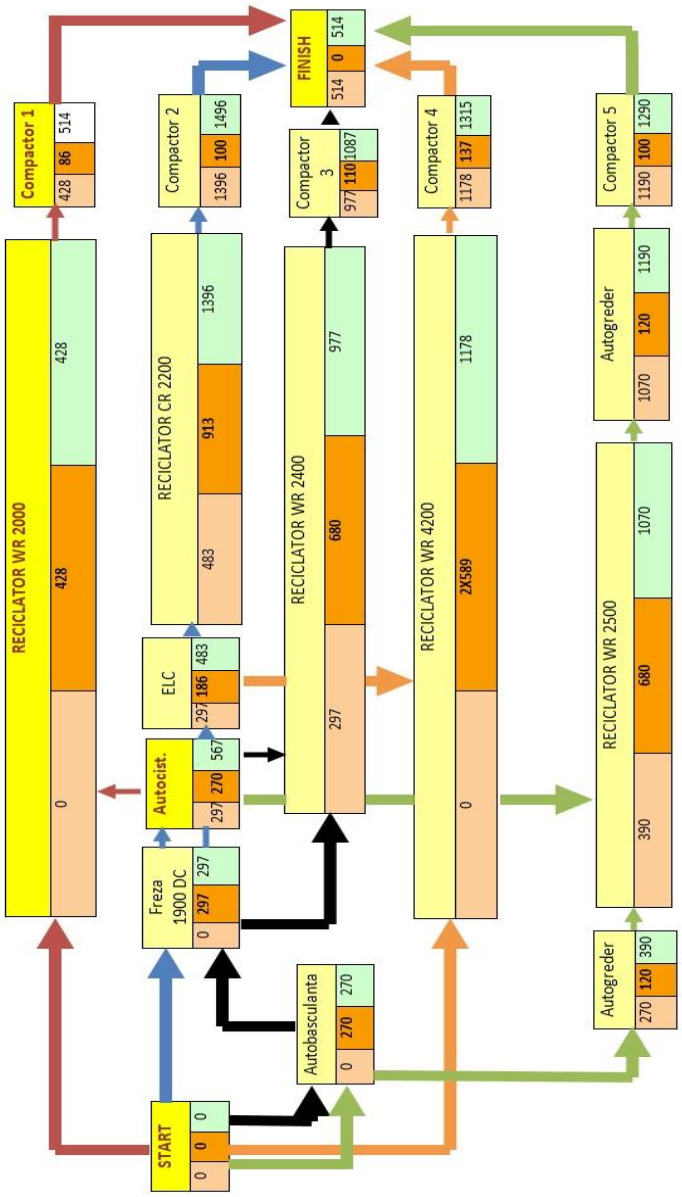


Figure 3. Graph for establishing the technological solution of mechanization having as a criterion the power requirement

5. CONCLUSIONS

1) Based on the operational concept of in situ recycling with the application of the general graph theory, the technological variant of mechanization with maximum efficiency was established, in the case of the process of rehabilitation of road works with cold, in situ recycling of the recovered materials.

2) The algorithmic stages were established according to the data of installed powers and real costs for the variants used, which led to the identification of two distinct processes corresponding to the two criteria, namely:

a) for the physical unit cost criterion, the recommended variant is represented by Sistema: dump truck for the addition of virgin aggregates, road mill for layer disaggregation, bituminous emulsion-added tanker, WR 2400 recycler for in situ recycling and compactor on tyres for final compaction;

b) for the installed power criterion, the recommended variant is represented by Sistema: tanker for joining binder, recycler WR 2000 for on-the-spot recycling of asphalt, without the addition of new materials and compactor for final compaction.

3) The selection of the recommended variant for the application is made taking into account the economic situation and the other associated technical and technological aspects;

4) Unit costs of production are influenced by the technological method of applied rehabilitation and the economic conjuncture of the moment at which it is made price analysis.

Compared to the above, it follows that the optimization method, based on the concept and the operational algorithm, can be applied to any type of work with the "in situ", cold recycling of used asphalt carpets using high-performance and dedicated technological equipment, with high speed of working and execution of recycled asphalt in reduced time intervals.

REFERENCES

[1] S. MOCANU, L. RECE, A. BURLACU, C. RONȚESCU, A. MODREA, *Novel Procedures for Sustainable Design in Structural Rehabilitation on Oversized Metal Structures*, METALS, Volume12, Issue7, Article Number1107 2023

[2] V. FLORESCU, S. MOCANU, L. RECE, L, D. MOTOUNU, A. GHERGHINA, A. BURLACU, *Design Contributions to the Elaboration of New Modeling Schemes for the Buckling Assessment of Hydraulic Actuators, METALS, Volume10, Issue9, Article Number1143. 2022*

[3] V. FLORESCU, S. MOCANU, A. NEAGU .C. SESCU-GAL, C, *Research on the parameters influencing the numerical analysis of the fatigue behaviour of a forklift-arm*, Romanian journal of transport infrastructure, Volume10, Issue1, Page1-10, DOI10.2478/rjti-2021-0001, JUL 2021

[4] V. FLORESCU, S. MOCANU, L. RECE, R. URSACHE N. GOGA, C.V. MARIAN, *Use of a Novel Resistive Strain Sensor Approach in an Experimental and Theoretical Study Concerning Large Spherical Storage Tank Structure Behavior During Its Operational Life and Pressure Tests*, SENSORS, Volume 20, Issue 2, Article Number 525, 2020

[5] A.LEGENDI, L. RECE, A.D.B. PIRONEA, V. FLORESCU, *Innovative calculation method of the productivity of vibrating screens used in mineral aggregates sorting*, Romanian journal of transport infrastructure, Volume 7, Issue 2, Page1-13, DOI 10.2478/rjti-2018-0008 DEC 2018

[6] P. BRATU, Ș. MIHĂILESCU., P. ZAFIU, ș.a. – "*Tehnologii și utilaje pentru executarea, întreținerea și reabilitarea suprastructurilor de drumuri*" vol. II "*Tehnologii și utilaje pentru repararea și reabilitarea drumurilor*", Ed. Impuls, București, **2005**;

[7] *"Wirtgen Cold Recycling Manual"*, Wirtgen GmbH, noiembrie **2004**;

[8] P. ZAFIU, A. GAIDOS: *Ingineria și managementul resurselor tehnologice în construcții"*, MATRIX ROM, București, **2001**

[9] P. BRATU, Ș, MIHĂILESCU, P. ZAFIU ș.a. – "*Tehnologii și utilaje pentru executarea, întreținerea și reabilitarea suprastructurilor de drumuri*", vol. IV "*Managementul proceselor tehnologice de construire, reabilitare și întreținere a drumurilor*", Editura Impuls, București, **2007**;

[10] O. TONCIU: *"Modelare procedee tehnologice de reciclare a materialelor asfaltice"*, raport de cercetare nr.2, U.T.C.B., București, **2007**;

[11] O. TONCIU: *"Aplicații privind optimizarea alocării resurselor tehnologice la procesele de reciclare a materialelor asfaltice"*, raport de cercetare nr. 3, U.T.C.B., București, **2009**;

[12] BURLACU. A., RACANEL C., "*Reducing cost of infrastructure works using new technologies*", 3rd International Conference on Road and Rail Infrastructure - CETRA 2014, "Road and Rail Infrastructure III", Proceedings of the Conference CETRA 2014, Dubrovnik, Split, 28-30 April 2014, ISSN: 1848-9842 (pg.189-pg.194)

[13] RACANEL C., BURLACU A., "*Environment protection by using new technologies for asphalt mixtures*", 3rd International Conference on Road and Rail Infrastructure - CETRA 2014, "Road and Rail Infrastructure III", Proceedings of the Conference CETRA 2014, Dubrovnik, Split, 28-30 April 2014, ISSN: 1848-9842 (pg.395-pg.400)

[14] POPESCU DIANA, BURLACU ADRIAN, "*Considerations on the benefits of using recyclable materials for road construction »*, ROMANIAN JOURNAL OF TRANSPORT INFRASTRUCTURE, Article No.4, pg. 43-53 Romanian Journal of Transport Infrastructure, Vol.6, July 2017, No.1, ISSN 2286-2218, ISSN-L 2286-2218

[15] ***, Prospecte comerciale ale firmei Wirtgen