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Public Economic Efficiency and Case-Based Reasoning: A Theoretical Framework to Police Performance

Javier Parra-Domínguez, Juan Manuel Corchado

***Abstract*—**At present, public efficiency is a concept that intends to maximize return on public investment focus on minimizing the use of resources and maximizing the outputs. The concept takes into account statistical criteria drawn up according to techniques such as DEA (Data Envelopment Analysis). The purpose of the current work is to consider, more precisely, the theoretical application of CBR (Case-Based Reasoning) from economics and computer science, as a preliminary step to improving the efficiency of law enforcement agencies (public sector). With the aim of increasing the efficiency of the public sector, we have entered into a phase whose main objective is the implementation of new technologies. Our main conclusion is that the application of computer techniques, such as CBR, has become key to the efficiency of the public sector, which continues to require economic valuation based on methodologies such as DEA. As a theoretical result and conclusion, the incorporation of CBR systems will reduce the number of inputs and increase, theoretically, the number of outputs generated based on previous computer knowledge.

***Keywords*—**Case-based reasoning, knowledge, police, public efficiency.

I. Introduction

THE use of new technologies plays a major role in increasing the efficiency of the public sector. Traditional application techniques, such as DEA, may be aided by methodologies such as CBR (Case-Based Reasoning), in their quest to minimize the use of resources and maximize results.

Public efficiency is a concept that intends to maximize return on public investment [1]; it has long been an important element of today's most advanced countries.

Various studies have focused not only on efficiency in the public sector but also on effectiveness [2], [3], specifically on improving management by objectives. There have also been several areas of study on public efficiency, in sectors such as health [4], education [5] and safety [6]-[8]. The focus of this work is police efficiency.

So far, the development of efficiency indicators has helped governments in their efforts to increase efficiency per se [9]. In our case, it has facilitated police work in crime prevention, investigation, detention, law enforcement and service.

By default, there are two main police forces. One has to do with crime prevention and control and the other has to do with direct protection and law enforcement. In general, most police efforts are devoted to investigative activities, which are aimed at identifying the perpetrator of an offense or of a set of specific crimes [10].

According to [11], police investigation can be divided into four phases. In the first phase, police officers use technology for personal efficiency (basic level system); in the second phase, police officers use technology to share information among themselves; in the third phase they acquire the knowledge that is then applied in a fourth phase. Fig. 1 shows the adaptation of the Gottschalk scheme in which the knowledge of the police officer and the technology are available at the same height. It is important to note that Gottschalk understood as technology word processing, spreadsheets, presentation software, etc.

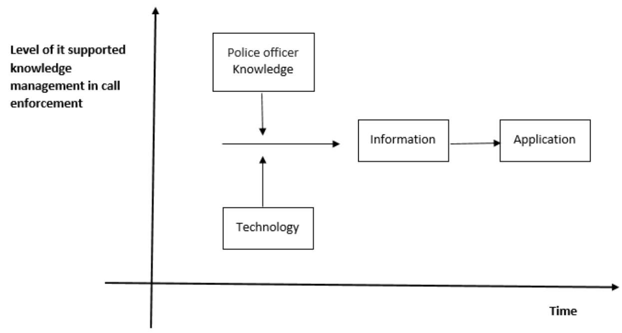

Fig. 1 Adaptation of the Gottschalk knowledge-technology scheme

The main objective of this article is to establish a direct relationship between the development of CBR and the economic efficiency of the public sector. This relationship will be established in a concrete study of law enforcement.

This article is structured as follows. The rest of this section is devoted to defining the theoretical aspects of the approach to efficiency and the CBR methodology. Then, the article describes some of the studies that combine CBR methodology and law enforcement. In the subsequent section, we examine the knowledge that exists to date in the application of CBR technology to law enforcement and economic efficiency in the public sector. Finally, we discuss principal conclusions.

A. Theoretical Development of the Concept Efficiency (Police Efficiency)

The activities carried out by the security forces, specifically by the police, are varied, which leads to problems when selecting a single indicator that can measure efficiency. The methodology of DEA emerges as an answer to this problem, a

Javier Parra is with the University of Salamanca, Spain (e-mail: javierparra@usal.es).

non-parametric technique developed by [12].

Efficiency is typically understood as the minimization of inputs (resources) and the maximization of outputs (results), and it is at this point where the DEA technique allows us to establish a relationship between both, since it only requires a correspondence between the inputs and outputs selected for our research. This includes inputs that are controlled by the police forces and those that are not.

DEA could be defined as the production technology that has multiple inputs and multiple outputs, where the inputs $x \epsilon Rd+$ are used in the production of $y \epsilon Rp+$ outputs and can be represented by the production set ψ of attainable input-output combinations:

$$\Psi = \{(x, y) \epsilon R_p^+ d\text{: x can produce y}\} \tag{1}$$

The technology is defined as $L(y) = \{x: (x, y) \epsilon \Psi\}$. The value of the efficiency measure is given by $\theta (x, y) = ||x|| / ||x^f||$ where, $\theta (x, y) = \min \{\theta: \theta_x \epsilon L(y)\}$, $x^f \epsilon IsoqL(y) = \{x: x \epsilon L(y), \mu x \notin L(y), \mu < 1\}$, is the frontier input.

One unit is considered as technically efficient if the efficiency measure equals one.

Following [13], the variable returns to scale (VRS) DEA efficiency estimators are given by the solution of the linear programs $\theta^{VRS} = \min \{\theta: \theta x_i \epsilon L^{VRS}{}_n (y_i)\}$. $L^{VRS}{}_n (y_i)$ is the piece-wise linear convex hull envelopment of the observed sample x_n given by $L^{VRS}{}_n (y_i) = \{x: y_i \leq Y_z, x \geq X_z, \sum^n i = 1z_i = 1, z \epsilon R^n{}_+\}$.

According to [14], the safest approach to estimating efficiency, which prevents potential misspecification, is the use of the VRS estimator. The Simar and Wilson (SW) algorithm, which calculates efficiency, could be improved by the application of bootstrapping techniques.

The SW algorithm is divided into the following steps:

1. Transform the input-output vectors using the original efficiency estimates $\{\theta, i = 1,..., n\}$ as $(x_{if} , y_i) = (xi\ \theta, y_i)$.
2. Generate smoothed resample pseudo-efficiencies γ_i^* as follows:

Given the set of estimated efficiencies $\{\theta\}$ use $h = 0{,}90n^{-1/5}\min \{\sigma_\theta, R_{13}/1.34\}$ to obtain the bandwidth parameter h.

Generate $\{\delta_i^*\}$ by resampling, with replacement, from the empirical distribution $\{\theta\}$ of the estimated efficiencies.

Generate the sequence $\{\delta_i^*\}$ using $\delta_i^* = \delta_i^* + h\varepsilon_i^*$ si $\delta_i^* + h\varepsilon_i^* \leq 1$; $2- (\delta_i^* + h\varepsilon_i^*)$ otherwise.

Generate the smoothed pseudo-efficiencies $\{\gamma_i^*\}$ using $\gamma_i^* = \delta_i^* +(\delta_i^* - \delta_i^{*a})/\surd 1 + h^2/\sigma_\theta^2$.

3. Let the bootstrap pseudo-data be given by $(x_i^*, y_i^*) = (x_i^f/ y_i^*, y_i)$.
4. Estimate the bootstrap efficiencies using the pseudo-data and the linear program $LVRSn (y_i) = \{x: y_i \leq Y_z, x \geq X_z, \sum_i^n = 1\ z_i = 1, z \epsilon R_n^+\}$ as $\theta^{SW*} = \min \{\theta: y_i \leq Y_z, \theta x_i \geq X{*}z, \sum_i^n = 1\ z_i = 1, z \epsilon R_n^+\}$.
5. Repeat step 2 to step 4 B times to create a set of *B* unit-specific bootstrapped efficiency estimates $\theta^{SW*,b}$, *i* = 1, . . ., *n*, *b* = 1, . . ., B.

From [15], Algorithm#1, in which step 3 is simply a parametric bootstrap of a regression model, consists of:

1. Using the original data obtained from the estimation of $L^{VRS}{}_n (y_i) = \{x : y_i \leq Y_z, x \geq X_z, \sum_{i=1}^n z_i = 1, z \epsilon R_n^+\}$ as $\theta^{SW*} = \min \{\theta : y_i \leq Y_z, \theta x_i \geq X * z, \sum_{i=1}^n z_i = 1, z \epsilon R_n^+\}$
2. Using the method of maximum likelihood to obtain an estimate ß* of ß, as well as an estimate σ_ε^* of σ_ε in the truncated regression of δ_i^* on z_i in $\delta_i^* = z_i ß + \zeta_i$ using m < n observations where $\delta_i > 1$.
3. Looping over the next three steps (1–3) L times to obtain a set of bootstrap estimates $D = \{(ß*, \sigma_\varepsilon^*)b\}_b{}^L = 1$. For each i = 1,…,m, draw ε_i from the $N(0, \sigma_\varepsilon^{*2})$ distribution with Leith-truncation at $(1 - z_i ß*)$. Again for each i = 1,…,m compute $\delta_i^* = z_i ß + \zeta_i$.

B. CBR

The CBR methodology aims to increase knowledge capturing efficiency. The initial premise of this methodology is the search for methods that are capable of inferring the best combination of various types of available knowledge [16].

It should be noted that the CBR methodology is based on knowledge gained from previous experiences, which is comparable to the study of analogies. Previous experiences can be used for different purposes, for example, to find solutions to new problems, identify possible problems, or to make predictions for the future and foresee the potential effects of a proposed solution [17].

The most common integrations of the CBR methodology are rule-based reasoning (RBR), model-based reasoning (MBR), constraint satisfaction problem (CSP) solving, information retrieval (IR) and planning approaches [18], [19]. The main activities performed by the CBR are those associated with the identification of relevant characteristics, from problem description, through past case retrieval, to the evaluation of the similarity of the old problem to the new problem and the evaluation of a possible solution through the adaptation of the old solution to the new problem.

II. Relationship between the CBR Methodology and Security Forces

This article focuses on the relationship between the CBR methodology and the economic efficiency of the public sector. However, before exploring this relationship, it is necessary to understand the connection between the CBR methodology and law enforcement, the topic of law enforcement is explored in depth in this article.

As previously mentioned, one of the most common integrations is RBR. In fact, CBR-RBR was one of the first modes of reasoning that was successfully integrated into the CBR methodology, designated for predominantly regulatory systems; the legal precedents of this mode are evident in the term “cases”. Although security forces follow an established order and are based mainly on the application of rules and norms, it is the integration of the reasoning modality that is applied to solve planning problems, a very important variable in the tasks of investigation of the outside of order. A good example of this integration is the one developed in the Joint Maritime Crisis Action Planning (JMCAP), which integrates

CBR with the hierarchical planning of military operations [20].

JMCAP concretely operated on the basis of past planning actions developed in military maritime crises of the past with the existing hierarchical network to model Human Planning processes more effectively. Subsequently, the planning operator HICAP was developed [21]; that is to say, templates describing how to divide goals into sub-goals and tasks, organizing the achievement of high-level objectives through their division into simpler, executive actions at lower levels. With HICAP, a set of objectives and a set of preconditions can be established. The key difference between operators and cases is that cases normally do not coincide entirely with the situation because of the dynamics of military work, so the indexing, retrieval, and application methods will differ.

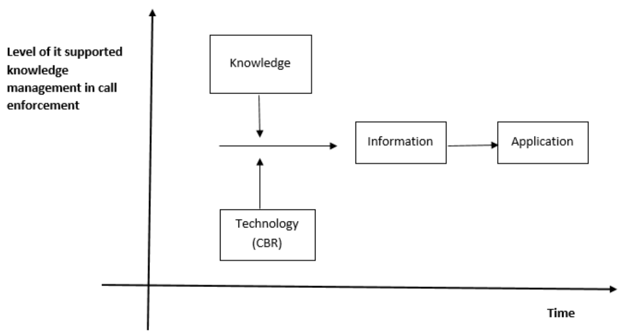

Fig. 2 Adaptation of the Gottschalk knowledge-technology scheme (with CBR technology)

This paper is primarily centred on the relationship between the application of the CBR methodology and the increment of the efficiency of police forces. The CBR methodology is generally applied when there is not a well-defined theory that focuses on what happened or why it happened [22]. In addition to the assumption that "similar problems have similar solutions", we are going to approximate the relationship between CBR and efficiency considering the particularity of the dynamic work of the police forces where all similar problems may not have similar solutions due to the established hierarchy and clear human interaction. The objective of the proposed relationship will be to increase the economic efficiency of the public sector, in our specific case, of the police forces.

Police investigation mainly focuses on solving crimes and apprehending offenders through solid evidence which allows the police to proceed with an arrest, and on the collection of evidence and testimonies for their presentation in court. There is a preliminary investigation, usually developed by officers, and a follow-up investigation normally carried out by detectives trained in investigation techniques [2]. In any case, the research tasks within the police forces are also subject to the existence of a hierarchy in an organization that makes variations in planning, as in the case of the US navy, according to a case study [19].

As it is possible to observe in Fig. 3, the aspects to be considered in the development of a good plan are assisted by the formulation of a plan with the characteristics that we could see.

It is important to highlight the application of CBR methodologies to police forces as far as possible to build bridges to close the gap that exists between the knowledge generated by the experience of the researcher and the methodologies and technology followed by the same, or by all the determined members of the police team. This is manifested when using forensic case data [23], which highlights the importance of analysis of serial burglary emphasizing of forensic science data, and in works where even new verticals of the CBR itself are proposed, as is the case of CBR-FT [24], where "Forensic Triager is a method for collecting and reusing past digital forensic research information in order to highlight likely evidence areas on a suspect operating system, thus helping an investigator to decide where to search for evidence".

III. Police Efficiency and CBR

As explained previously, the main motivation of this work is to directly relate the economic efficiency of the public sector with the implementation of the CBR methodology. In this article, this is done through the study of how CBR contributes to the efficiency of police at work. Efficiency has been directly associated with CBR methodologies in the state of the art, as in the case of Oil Well Drilling [25], where the CBR method was used, for the repair and prevention of possible breakdowns in drilling oil wells in the open sea.

Police work is dynamic, complex and stressful because it involves carrying out numerous tasks. It is necessary to raise awareness among the police community about the benefits of adopting information technologies at work. Thanks to technology, the quality of police work will be higher, and the knowledge of the organization will increase, making the completion of tasks more efficient [26].

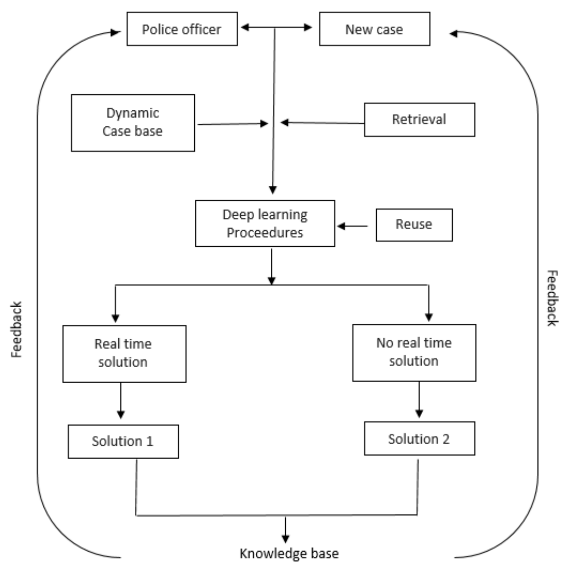

Fig. 3 Adaptation of the Gottschalk knowledge-technology scheme (with CBR technology)

A good example of a successful integration of an information technology system is COPLINK (System Usability and User Acceptance Evaluations) [27], developed by the Artificial Intelligence Lab at the University of Arizona, in collaboration with TPD. COPLINK acts as a knowledge management system designed for enhanced information sharing and provides knowledge management support to individual officers within and across law enforcement agencies. Thanks to the use of COPLINK, the officer is able to perform their tasks more efficiently, making law enforcement more agile.

New techniques are being incorporated strategically to provide support and efficiency to police investigations by reducing the resources used in the process. Invaluable visualization techniques [28], [29] designed specifically for police investigation, are capable of identifying patterns that help resolve crimes, for example, on social networks [30], or also techniques that are better at detecting human activity [31]. All these techniques contribute to increasing efficiency and reducing the use of police resources.

The PRODIGY architecture, in fact, was designed both as a unified testbed for different learning methods and as a general architecture for solving problems in complex task domains.

The above techniques have in common the importance of planning based on certain cases that guide the search for solutions; understanding by this search offers a greater efficiency than in the traditional principles (derivative analogy that allows saving problems). In general, the current dynamic is based on the use of processes instead of solutions to specific problems.

IV. Discussion and Future Works

The conclusion drawn from the theoretical framework provided in this article is that the current concept of efficiency could be expanded upon in the direct relationship between the CBR methodology and efficiency in public economics.

The principles of efficiency tell us to strive towards reducing the inputs in the development of a set of outputs, where inputs are understood as public resources and outputs as what results from the application of those resources. The use of a lower number of resources or inputs is an intrinsic feature of the CBR methodology because, among other things, it applies new technologies in what could be called the first part of the process and which was first developed using the model described in the PRODIGY Algorithm developed by [32].

The inclusion of the CBR methodology in the concept of efficiency in public economics, leads us to think that in the future this methodology will be implemented in all the public processes that involve public spending or that represent the consumption of public resources.

In the present work, the public efficiency of police forces has been taken as an example, but it is unquestionable that the same concept can be applied to multiple areas within the sector of public economics. It is not necessary to look far to find other cases, prior to the study of public efficiency, where CBR has been applied. It has for example been applied in education, a sector that also involves public spending and generates results in the form of grades or student satisfaction. Also, specific public resources are invested in the health sector and the results include shorter waiting list and patient satisfaction.

The future challenges will lie in extending and scaling the CBR methodology, for example, if we want to apply CBR strategically in the health sector, where activities such as planning take place e.g. knowledge-based treatment planning for early intervention in cases of mental health in adolescents [33]. Likewise, it will be challenging to implement it at a tacit level, for example in the education sector where different cognitive CBR models could be incorporated [34].

In any case, the application of the CBR methodology in public economics will result in greater efficiency.

References

[1] Afonso, A., Schuknecht, L., & Tanzi, V., “Public sector efficiency: an international comparison”. *Public choice* 123(3-4), 321-347 (2005).

[2] Getie Mihret, D., & Wondim Yismaw, A., “Internal audit effectiveness: an Ethiopian public sector case study” 22(5), 470-484 (2007).

[3] Mandl, U., Dierx, A., & Ilzkovitz, F., “The effectiveness and efficiency of public spending (no. 301)”. *Directorate General Economic and Financial Affairs (DG ECFIN)*, European Commission.

[4] Riddiough, M.A., Sisk, J.E., & Bell, J.C., “Influenza vaccination: cost-effectiveness and public policy”. *Jama* 249(23), 3189-3195 (1983).

[5] Jackson, G.A., “Public efficiency and private choice in higher education”. *Educational evaluation and policy analysis* 4(2), 237-247 (1982).

[6] García Sánchez, I.M., Rodríguez-Domínguez, L., & Domínguez, J.P., “Evaluation of the efficacy and effectiveness of the Spanish security forces”. *European Journal of Law and Economics* 36(1), 57-75 (2013).

[7] García Sánchez, I.M., Rodríguez-Domínguez, L., & Domínguez, J.P., “Yearly evolution of police efficiency in Spain and explanatory factors”. *Central European Journal of Operations Research* 21(1), 31-62 (2013).

[8] Thanassoulis, E., “Assessing police forces in England and Wales using data envelopment analysis”. *European Journal of Operational Research* 87(3), 641-657 (1995).

[9] Collier, P.M., “In search of purpose and priorities: Police Performance indicators in England and Wales. *Public Money and Management* 26(3), 165-172 (2006).

[10] Simar, L. & Wilson, P.W.: A general methodology for bootstrapping in non-parametric frontier models. *Journal of Applied Statistics* 27(6), 779-802 (2000).

[11] Gottschalk, P., “Stages of knowledge management systems in police investigations”. *Knowledge-Based Systems* 19(6), 381-387 (2006).

[12] Charnes, A., Cooper, W.W., & Rhodes, E., “Measuring the efficiency of decision-making units”. *European Journal of Operational Research* 2(6), 429-444 (1978).

[13] Banker, R. D., Charnes, A., & Cooper, W. W., “Some models for estimating technical and scale inefficiencies in data envelopment analysis”. *Management science*, 30(9), 1078-1092 (1984).

[14] Simar, L. & Wilson, P.W., “Statistical inference in nonparametric frontier models: The state of the art”. *Journal of Productivity Analysis* 13(1), 49-78 (2000).

[15] Simar, L. & Wilson, P.W.: Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of Econometrics* 136(1), 31-64 (2007).

[16] Aamodt, A., “Explanation-driven case-based reasoning”. *In: European Workshop on Case-Based Reasoning*, pp. 274-288. Springer, Berlin (1993).

[17] Kolodner, J.L., “An Introduction to Case-Based Reasoning”. *Artificial Intelligence Review* 6, 3-34 (1992).

[18] Greene, D., Freyne, J., Smyth, B., & Cunningham, P., “An analysis of current trends in CBR research using multi-view clustering”. *AI Magazine*31(2),45-61(2010).

[19] Marling, C., Rissland, E., & Aamodt, A., “Integrations with case-based reasoning”. *The Knowledge Engineering Review* 20(3), 241–245 (2005).

[20] desJardins, M., Francis, A., & Wolverton, M., “Hybrid planning: An approach to integration generative and case-based planning”. *In:*

Working Notes of the AAAI-98 Workshop on Case-Based Reasoning Integrations. (1998).

[21] Muñoz-Avila, H., McFarlane, D.C., Aha. D.W., Breslow, L., Ballas, J.A., & Nau, D.S., "Using guidelines to constrain interactive case-based HTN planning". *In: International Conference on Case-Based Reasoning*, pp. 288-302. Springer, Berlin. (1999).

[22] Craw, S., & Aamodt, A., "Case Based Reasoning as a model for Cognitive Intelligence, *In: International Conference on Case-Based Reasoning*, pp. 62-77. Springer, Cham. (2018).

[23] Ribaux, O., & Margot, P., "Case based reasoning in criminal intelligence using forensic case data". *Science & Justice* 43(3), 135-143 (2003).

[24] Horsman, G., Laig, C., & Vickers, P., "A case-based reasoning method for locating evidence during digital forensic device triage". *Decision Support Systems* 61, 69-78 (2014).

[25] Skalle, P., Sveen, J., & Aamodt, A.: Improved efficiency of oil well drilling through case-based reasoning. *In: Pacific Rim International Conference on Artificial Intelligence*, pp. 712-722. Springer, Berlin. (2000).

[26] Luen, T.W. & AI-Hawamdeh, S., "Knowledge management in the public sector: principles and practices in police work". *Journal of Information Science* 27(5), 311-318 (2001).

[27] Lin, C., Hu, P.J.H., & Chen, H., "Technology implementation management in law enforcement: COPLINK system usability and user acceptance evaluations". *Social Science Computer Review* 22(1), 24-36 (2004).

[28] Chen, H., Atabakhsh, H., Tseng, C., Marshall, B., Kaza, S., Eggers, S., … & Violette, C., "Visualization in law enforcement". *In: CHI'05 extended abstracts on Human factors in computing systems*, pp. 1268-1271. ACM. (2005).

[29] Richter, M.M., "Knowledge containers. Readings in Case-Based Reasoning". *Morgan Kaufman Publishers* (2003).

[30] López-Sánchez, D., Corchado, J.M., & Arrieta, A.G., "Dynamic detection of radical profiles in social networks using image feature descriptors and a Case-Based reasoning methodology". *In: International Conference on Case-Based Reasoning*, pp. 219-232. Springer, Cham. (2018).

[31] Wijekoon, A., Wiratunga, N., Sani, S., Massie, S., & Cooper, K., "Improving kNN for Human Activity recognition with priviledge learning using translation models". *In: International Conference on Case-Based Reasoning*, pp. 448-463. Springer, Cham. (2018).

[32] Veloso, M.M., & Carbonell, J.G., "Derivational analogy in PRODIGY: Automating case acquisition, storage, and utilization". *In: Case-Based Learning*, pp. 55-84. Springer, Boston (1993).

[33] Wang, W.M., Cheung, C.F., Lee, W.B., & Kwok, S.K., "Knowledge-based treatment planning for adolescent early intervention of mental healthcare: a hybrid case-based reasoning approach". *Expert System* 24(4), 232-251 (2007).

[34] Kolodner, J.L., Cox, M.T., & González-Calero, P.A., "Case-based reasoning-inspired approaches to education". *The Knowledge Engineering Review* 20(3), 299-303 (2005).