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Automobile speed-breaker system mechanisms analysis: complex proportional assessment approach

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ABSTRACT

Automobile speed-breaker systems constructed across major roads in many developing countries are primarily meant to control and reduce accidents caused by over-speeding. Recently studies show that renewable energy could be generated from speed breaker systems. These systems have been improved for kinetic energy of moving vehicles to be converted into electricity to power street lights, road signs and traffic lights. The concern of majority of decision makers has been how to select the best-fit design out of many different mechanisms speed-breaker systems. The purpose of this paper is to develop a methodology for prioritizing the different mechanism of the speed-breaker system in order to effectively determine the most suitable mechanism for power generation. The proposed technique integrated Complex Proportional Assessment (COPRAS) and Standard Deviation (SDV) methods. While the SDV approach was applied to determine decision criteria weights, the COPRAS technique was used to rank the different mechanism. A case study was performed using the technique and result showed that roller systems were best-fit out of the three mechanisms assessed. The method is beneficial because it can easily be applied to assess the benefits of a range of options without taking too much computation space, but with proper priority-based ranking of all important factors.

Keywords: Speed breaker system, mechanisms, COPRAS, electric power, decision criteria

1. INTRODUCTION

Automobile speed-breaker constructed along major roads in most developing countries are primarily designed to alert drivers to reduce vehicular speed, especially in areas with high human traffic, in order to minimize or eliminate accidents. Due to tremendous increase in population and industrialization, the demand for electric power has increased geometrically without a corresponding improvement in power generation in majority of developing countries. To meet up with the demand of electric power, researchers have advocated for the application of speed breaker systems as source of energy in addition to existing sources such as fossil fuel, biomass, solar and wind.

To achieve the aim of utilizing speed breaker system as a potential source of energy, the system itself has been modernized in such a way that energy can be tapped from vehicles passing over it. The different speed breaker system mechanism discussed in this work are already being implemented in some developing countries and include; roller mechanism, rack and pinion mechanism, crankshaft mechanism and air piston mechanism.

Kolhe and Pandhare (2017) designed and constructed a speed breaker system utilizing the rack and pinion mechanism. The system produced was capable of converting kinetic energy of vehicles passing through the speed breaker into mechanical energy of the shaft. The energy was used to drive a generator to produce electric power. Mishra (2013) also applied the rack and pinion mechanism to design a speed breaker system for power generation. Bhagdika et al. (2014) applied the roller mechanism in the design of a speed breaker system for the purpose of generating electric power. Patil et al, (2017) proposed a speed breaker system using spur gear and chain drive mechanism to tap energy from vehicles passing through it and generate electricity. Rokonozaaman and Hossam-E-Haider (2015) proposed a hybrid speed-breaker system utilizing a combination of roller mechanism and rack and pinion mechanism. A major observation is that the hybrid methodology is more efficient than the single mechanism system.

In many of the aforementioned research, the focus was mostly the design of different mechanism for power generation and not necessarily how to choose or select one out of many options.

The different mechanisms have been compared in some studies. Jagtap et al., (2014) discussed and compared three speed breaker mechanisms; roller, rack and pinion and air piston mechanisms. The optimum mechanism for power generation was determined by the authors through mere physical comparison of the data of five decision criteria; cost, mechanism set up, maintenance, efficiency and design. However, a mere visual comparison is not sufficient to determine the best speed breaker mechanism for power generation because decision making process involves multiple criteria which are usually conflicting. For example, efficiency is a case of maximization while cost is a case of minimization. Furthermore, as the number of alternatives and decision criteria increases, the complexity of the decision making process increases. There is the issue of decision criteria weights disparity which the authors did not put into consideration. It has also been established in literature that decision problem involving multiple criteria can be resolved appropriately using a Multi-Criteria Decision Making (MCDM) approach (Emovon et al., 2016; Sachdeva, 2009; Opricovic and Tzeng, 2004). In this paper, aComplex Proportional Assessment (COPRAS) approach is proposed for addressing the issue of selecting the best-fit automobile speed breaker system mechanism. The COPRAS method is an MCDM tool and was the approach of choice because of its ease of implementation and simplicity when compared to other tools such as PROMETHEE and ELECTRE methods.

2. AUTOMOBILE SPEED BREAKER SYSTEM

The automobile speed-breaker system constructed in major roads in many developing countries is meant to control and reduce the risk of accidents. Speed-breaker systems are developed in such a way that energy produced by passing vehicle is tapped-off to generate electricity to power streets lights and traffic lights. To achievethis objective the objective of this paper, different speed breaker system design are highlighted as follows:

Roller mechanism (Jagtap et al., 2014): The design utilizes an iron roller which is fixed on a wooden ramp and as vehicles passes over it, the roller rotates. The roller in turn rotates the generator shaft connected to it with the aid of chain and sprocket arrangement and in the process electric power is generated.

Rack and Pinion mechanism (Rokonuzzaman and Hossam-E-Haider, 2015): In this approach, the speed breaker is positioned at the top of the entire system and it is directly linked to a rack. A small sprocket (pinion) is connected to the rack and as the rack moves downward, the small pinion rotates which also results to the rotation of a larger pinion linked to it with the aid of a shaft. The generator shaft directly connected to the larger pinion automatically rotates due to the rotation of pinions and in the process electricity is generated. The above description of the Rack and Pinion mechanism is diagrammatically represented in Figure 1.

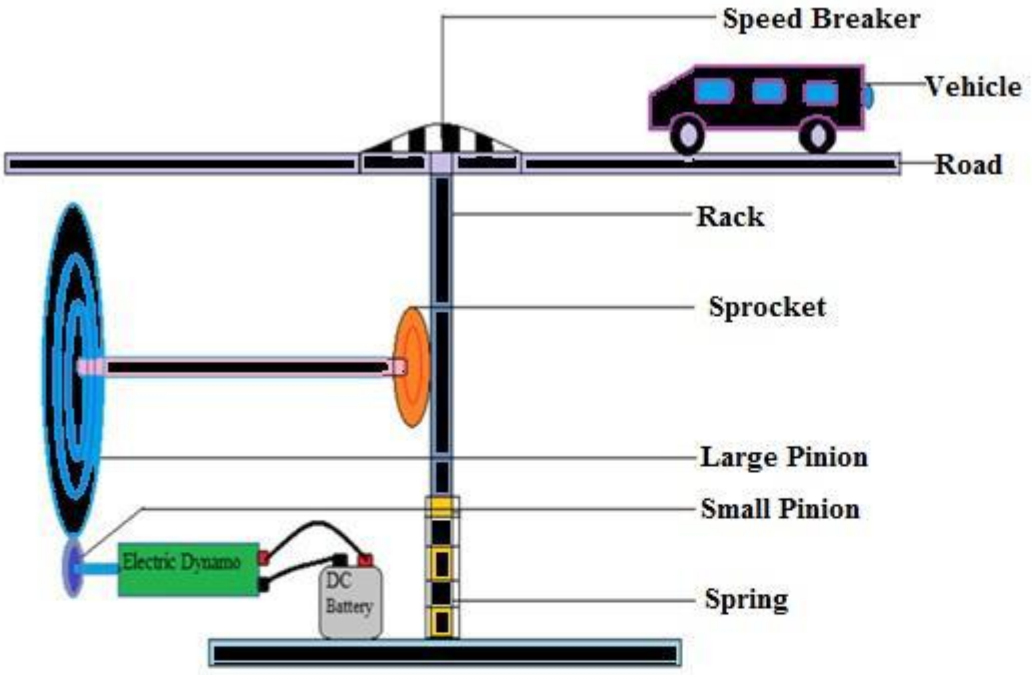

Figure 1
Rack and pinion mechanism (Hossam-E-Haider and Rokonuzzaman, 2015)

Air Piston mechanism (Jagtap et al., 2014): In this methodology, the speed breaker is produced using a metal sheet in the form of a dome and then supported by spring stands. The dome is linked via a connecting rod to a piston housed in an air compressor cylinder. As vehicles pass over the dome, the reciprocating movement of the piston within the air compressor cylinder results in the rotary motion of the generator shaft.

Apart from the three mechanisms described in this work, other designs have been proposed and they include: crank shaft mechanism and lever mechanism (Gupta, et al., 2013).

3. METHODOLOGY

The proposed methodology consists of capabilities of the SDV and COPRAS approach. The weights of decision criteria (cost, mechanism set up, maintenance, efficiency and design) are evaluated with SDV whilst ranking of the alternatives (different speed breaker system mechanisms) is performed with the COPRAS method. The two techniques are discussed as follows:

3.1. Standard Deviation (SDV)

The weights of decision criteria are central to the decision making process involving conflicting decision criteria. The objective approach applied in determining criteria weights is the SDV approach. It is objective because it accounts for the variation across each of the decision criteria.

The SDV steps are as follows (Mohamed and Ahmed 2012):
Step 1. The decision matrix formation and it is indicated as Table 1.

Step 2. Normalization of the decision matrix as follows:

$$Q_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (1)$$

Where Qij is the normalised matrix.

Step 3: Evaluation of SDV

$$sDV_j = \sqrt{\frac{1}{m}\sum_{i=1}^{m}\left(Q_{ij} - \overline{Q_{ij}}\right)^2} \quad (2)$$

Where $\overline{Q_{ij}}$ is the mean of the normalised matrix

Step 4: The evaluation of decision criteria weights as follows:

$$W_j = \frac{sDV_j}{\sum_{j=1}^{n} sDV_j} \quad (3)$$

Table 1 Decision matrix

Alternatives (Ai)	Decision criteria (Cj)					
	C1	C2	C3	-	-	Cn
A_1	x_{11}	x_{12}	x_{13}	-	-	x_{1n}
A_2	x_{21}	x_{22}	x_{23}	-	-	x_{2n}
A_3	x_{31}	x_{32}	x_{33}	-	-	x_{3n}
-	-	-	-	-	-	-
-	-	-	-	-	-	-
A_m	x_{m1}	x_{m2}	x_{m3}	-	-	x_{mn}

Where
A_i designates the alternatives and i =1, 2, …m
C_j indicates the decision criteria and j = 1, 2,…n
x_{ij} is the assigned rating to alternative i with respect to the j^{th} criterion.

3.2. COPRAS method

COPRAS is an acronym for Complex Proportional Assessment, an MCDM tool developed by Zavadskas (Madic et al. 2014). In decision making process, it works by selecting the best alternative with regards to ideal and anti-ideal solutions (Madic et al. 2014).

The use of the approach in solving multi-criteria decision problem has been reported in many literatures. Chatterjee and Chakraborty (2013) applied the technique for solving a gear material selection problem. Petkovic et al., (2015) proposed the application of COPRAS method in selecting the most appropriate non-conventional machining processes for machining ceramics.

The steps for obtaining best solution using the approach includes (Chatterjee et al. 2011):
Step 1. Formation of decision matrix. An example is shown in Table 1.
Step 2: Normalization of the decision matrix using Eq. 1.
Step 3. Evaluation of the weighted normalised matrix using the following expression:

$$P_{ij} = Q_{ij}.w_j \ (4)$$

Step 4. Summation of the benefits and non-benefits criteria values respectively as follows:

$$R_{+i} = \sum_{j=1}^{n} P_{+ij} \ (5)$$

$$R_{-i} = \sum_{j=1}^{n} P_{-ij} \ (6)$$

Where P_{+ij} and P_{-ijs} denote values of weighted normalised decision matrix for benefit and non-benefit criteria respectively.

Step 5. Evaluation of the relative importance of alternatives, Y, as follows:

$$Y_i = R_{+i} + \frac{R_{-min}.\sum_{i=1}^{m} R_{-i}}{R_{-i}.\sum_{i=1}^{m}\left({}^{R_{-min}}/_{R_{-i}}\right)} \ (7)$$

Step 6. Evaluation of performance index of the i-th alternative using the following expression:

$$Z_i = \frac{y_i}{Y_{max}} * 100 \qquad (8)$$

Where Ymax is the maximum value of Yi
The alternatives are then ranked, based on the performance index, Z.

4. DATA COLLECTION, ANALYSIS AND DISCUSSIONS

To demonstrate the suitability of the COPRAS method in the ranking of different speed breaker mechanism for power generation, data was obtained from the work of (Jagtap et al., 2014) and used as case study. The data obtained is presented in Table 2.

Table 2 Comparison of mechanisms (Jagtap et al., 2014)

Mechanisms	Decision criteria				
	Cost	Mechanism Set up	Maintenance	Efficiency	Design
Roller Mechanism	Cheap	Very Easy	Less Required	~50%	Easy to design
Rack and Pinion Mechanism	Moderate	Difficult	Weekly Basis	~70%	Depends upon weight sustaining capacity

Air Piston Mechanism	Costly	Very Difficult	Daily Basis	~85%	Depends upon compressing power of air pistons

Three different speed breaker mechanisms; roller, rack and pinion and air piston mechanisms were compared using five decision criteria; cost, mechanism set up, maintenance, efficiency and design. Looking at the data presented in table 2, the best option is not clear. Amere visualization of different parameters of alternatives is not sufficient to determine which one is optimum because the decision making process involves multiple criterion which are conflicting. For example, efficiency is a case maximization while cost is a case of minimization. Furthermore, as the alternatives and decision criteria increases, decision making process complexity increases. There is also the issue of decision criteria weights differential which was not put into consideration in the work. Hence, the use of COPRAS approach in determining optimum solution in this paper.

Table 3 Decision matrix

Mechanisms	Decision criteria				
	Cost (C1)	Mechanism Set up (C2)	Maintenance (C3)	Efficiency (C4) (%)	Design (C5)
Roller Mechanism	1	1	1	50	1
Rack and Pinion Mechanism	2	2	2	70	3
Air Piston Mechanism	3	3	3	85	3
Criteria type	Min	Min	Min	Max	Min

Table 4 Normalized matrix

Mechanisms	C1	C2	C3	C4	C5
Roller	0.1667	0.1667	0.1667	0.2439	0.1429
Rack and Pinion	0.3333	0.3333	0.3333	0.3415	0.4286
Air piston	0.5000	0.5000	0.5000	0.4146	0.4286

The information in Table 2 was then transformed into a format, which can easily be applied to the COPRAS methodology using a three-point likert scale. The result obtained, formed a decision matrix and is shown in Table 3.

The decision matrix in Table 3 is applied as input data into the COPRAS methodology to determine the optimum mechanism. Prior to this analysis, the weight of the decision criteria is determined using the SDV approach. Applying the SDV, weights of C1, C2, C3, C4 and C5 were obtained as 0.2090, 0.2090, 0.2090, 0.1652 and 0.2079 respectively. Having known weights of decision criteria, COPRAS methodological steps are applied to rank the different mechanisms. The first step is to normalize data in Table 3 using Eq. 1 and the result is presented in Table 4. The weighted normalized matrix is then obtained by applying Eq. 4 on the normalized matrix and the weights of decision criteria produced by the SDV method. The result generated is shown in Table 5.This is followed by the summation of the benefit and non-benefit criteria using Eq. 5 and 6.Finally, applying Eq. 7 and 8, the relative importance and performance index of the different speed breaker mechanisms are evaluated and the results produced are presented in Table 6. The mechanisms are ranked based on the performance index and the ranks are also shown in Table 6.

Table 5 Weighted normalized matrix

Mechanism	C1	C2	C3	C4	C5
Roller	0.0348	0.0348	0.0348	0.0403	0.0297
Rack and Pinion	0.0697	0.0697	0.0697	0.0564	0.0891
Air piston	0.1045	0.1045	0.1045	0.0685	0.0891

Table 6 Mechanisms performance index and ranks

Mechanism	Y	Z	Rank
Roller	0.5084	100	1
Rack and Pinion	0.2672	53	2
Air piston	0.2245	44	3

From Table 6, the best speed breaker mechanism for power generation based on the data fed to the COPRAS method is the roller mechanism; having scored 100 percent. This is followed by the Rack and Pinion mechanism having scored 53 percent while the worst ranked is the Air piston having scored 44 percent. The COPRAS method was applied in this paper because of its simplicity of application, compared to some other multi-criteria decision making (MCDM) tools such as PROMETHEE and ELECTRE methods. The uses of the MCDM approach have numerous advantages over the approach previous authors in the literature used to determine optimum solution. The merits of the MCDM approach include: (1) the ability of the decision maker to allocate weights to decision criteria in order of importance to their organization and (2) the ease of determining the optimum solution without doubt due to the rank index allocated to different criteria and (3) the ease of obtaining optimum solution irrespective of the numbers of alternatives and decision criteria. These advantages set the method apart from others.

5. CONCLUSION

This paper presented a methodology for selecting optimum speed-breaker system mechanism for effective power generation. The proposed technique combines COPRAS and SD methods. The SD method was applied in evaluating weights of five decision criteria; cost, mechanism set-up, maintenance, efficiency and design while COPRAS method was applied in the ranking of three speed breaker system mechanisms; roller, rack and pinion and air piston mechanisms. The developed method was applied to a case study. The result of the comparative analysis showed that the roller mechanism is the most suitable for power generation. The COPRAS method was chosen for this analysis because it is simpler to apply when compared to other MCDM techniques such as PROMETHEE and ELECTRE methods. Therefore, the proposed method can easily be implemented in developing countries where there might be multiple criteria and other expert selection techniques are expensive to implement. For future work, other speed breaker mechanisms such as crank shaft, lever and hybrid mechanisms can be included in the decision making process. The inclusion of more decision criteria can also be explored, in order to attain a more robust decision.

DISCLOSURE STATEMENT

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REFERENCE

1. Bhagdikar P, Gupta S, Rana N, Jegadeeshwaran R. Generation of Electricity with the use of speed breakers. *International Journal of Advances in Engineering & Technology*, 2014, *7*(2), 589 – 595.

2. Chatterjee P, Athawale VM, Chakraborty S. Material selection using complex proportional assessment and evaluation of mixed data methods. *Materials & Design*, 2011, 32(2), 851-860.
3. Chatterjee P, Chakraborty S. Gear material selection using complex proportional assessment and additive ratio assessment-based approaches: a comparative study. *International Journal of Materials Science and Engineering*, 2013, 1(2), 104-11.
4. Emovon I, Norman RA, Murphy AJ. An integration of multi-criteria decision making techniques with a delay time model for determination of inspection intervals for marine machinery systems. *Applied Ocean Research*, 2016, 59, 65-82.
5. Gupta R, Sharma S, Gaykawad S. A Revolutionary Technique of Power Generation through Speed Breaker Power Generators. *International Journal of Engineering Research and Technology*, 2013, 2(8), 1879-1883
6. Hossam-E-Haider M, Rokonuzzaman M. "Design of an Efficient Energy Generating Systems Using Speed Breaker for Bangladesh" The 5th National Symposium on Information Technology: Towards Smart World from 17-19 February, 2015, King Saud University (KSU), Riyadh, Saudi Arabia.
7. Jagtap PD, Pardeshi SD, Khade AG, Sathe V. A Review: Comparison of different Mechanisms for Electricity Generation using Speed Breaker. Multidisciplinary journal of Research in Engineering and Technology, 2014, 1(2), 202-206.
8. Kolhe K, Pandhare A. Electric Power Generation System from Speed Breaker by using Rack and Pinion Mechanism. International journal of current Engineering and Technology, 2017, 7(3), 1151-1158
9. Madić M, Marković D, Petrović G, Radovanović M. APPLICATION OF COPRAS METHOD FOR SUPPLIER SELECTION. In *Proceedings of 5th International Conference Transport and Logistics, ISBN* (pp. 978-86).
10. Mohamed F, Ahmed AN. Analysis of project selection by using SDV-MOORA approach. *Life Science Journal*, 2012, *9*(2), 129-131
11. Mishra A, Kale P, Kamble A. Electricity Generation from Speed Breakers. *The International Journal of Engineering and Science (IJES)*, 2013, 2(11), 25-27.
12. OpricovicS, Tzeng GH. Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European journal of operational research*, 2004, 156(2), 445-455.
13. Patil B, Gaikwad S S, Halankar MS, Patil SP, Sandilya AV. Power Generation from Speed Breaker, *SSRG International Journal of Mechanical Engineering (SSRG-IJME),* 2017, 4, 3
14. Petkovic D, Madic M, Radenkovic G. Selection of the most suitable non-conventional machining processes for ceramics machining by using MCDMs. *Science of Sintering*, 2015, 47(2), 229.
15. Rokonuzzaman M, Hossam-E-Haider M. Analysis of Speed Breaker Mechanism for More Effective Electricity Generation. International Conference on Mechanical, Industrial and Materials Engineering 2015 (ICMIME2015) 11-13 December, 2015, RUET, Rajshahi, Bangladesh.
16. Sachdeva A, Kumar D, Kumar P. Multi-factor failure mode critically analysis using TOPSIS. *Journal of Industrial Engineering International*, 2009, 5(8), 1-9.