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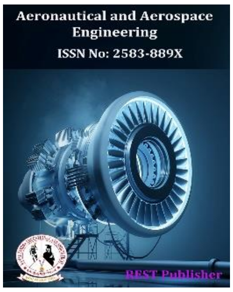

Solving the Conveyor Selection Problems in a Manufacturing Industry with the Grey Relational Analysis (GRA) Technique

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Abstract: *The most crucial component of modern production systems, "material handling equipment (MHE)", is becoming increasingly crucial to the plant's effectiveness. Due to the significant capital expenditure needed, choosing the best MHE is a very difficult and complicated undertaking for fabrication organizations. The choice of "material handling equipment (MHE) is a multi-criterion decision-making (MCDM)" problem that is continually growing and is impacted by a wide range of factors. An important factor in determining a manufacturing organization's effectiveness and competitiveness on the world market is the appropriate decision of MHE. It is expensive and time to choose the best MHE for a particular engineering purpose, and numerous candidate options on the marketplace are taken into consideration as the first options. It has been discovered that using "multiple criteria decision making (MCDM)" is an effective method for analysing these competing aspects. Language is typically used to express the language assessment of "MHE options within the context of numerous subjective judgments and the weights of the factors". The GRA is used in this research to solve the conveyor picking issue. The decision is made based on how well the conveyor and operational features mesh. The goal is to choose a conveyor that is both cost- and energy-efficient. The rank for Conveyor 1 is third, Conveyor 2 is second, Conveyor 3 is first, and Conveyor 4 is fourth. The ranking order is "C3 > C2 > C1 > C4". Conveyor 3 was discovered to be the best conveyor among the selected alternate conveyors, as per the Grey Relational Analysis (GRA) technique. The people who make decisions' desire for choosing the best conveyor was significantly influenced by "Item weight, Flexibility, and Speed of conveyor."*

Keywords: *Conveyor, Material handling equipment, Grey system, Speed of conveyor, Item weight and Flexibility and MCDM.*

1. INTRODUCTION

A relatively brief movement that typically occurs inside the walls of a facility, like a plant or a storehouse, as well as between a structure and a conveyance agency, is referred to as "material handling (MH)". Contrary to production (i.e., manufacture and assembly processes), which provides "form utility" by altering "the shape, form, and composition of material", it can be utilized to create "time and place utility" through the processing, storage, and management of material [1]. It is frequently asserted that MH simply increases a company's financial performance and does not increase its worth. While "MH does not give a product form usefulness, the moment and location utility" it offers can raise the benefits of a brand after MH has occurred [2]. Consideration of MH as a cost that should be minimized is a frequent approach to the development of MH solutions (MHSs). While MH can bring significant value to the goods, it is typically challenging to detect and measure the advantages of MH; in contrast, it is much simpler to detect and measure the expenses of MH. For this reason, this technique may be the most effective in many cases ("the cost of MH equipment, the cost of indirect MH labor") [3]. Substitute MHS projects are designed after the design of a manufacturing operation is finished, excluding MH implications. Each of these designs fulfils the MH criteria of the manufacturing phase. Next, the MHS design with the lowest cost is chosen. Depending on how much the other components of the assembly process can be altered, it may be fair to use MHS price as the only factor for choosing an MHS architecture [4]. The price of the commodity is the best criterion to employ when choosing an MHS if a brand-new facility and method of manufacture are being constructed; the least expensive MHS might not produce the least total price of production. The only factor that needs to be considered is MHS expense if it is too expensive to even contemplate modifying the fundamental design of a building and the manufacturing methods [5]. Unless a new factory and production line are being planned, it can be challenging to consider all the costs of complete production aspects at once in actual practice. The design elements that have the biggest influence on overall cost are eventually fixed and turn into limitations for the other design elements [6]. "A mechanical handling device" for quickly and effectively moving loads and commodities automatically around a space is a conveyor machine. Among other advantages, this technology minimizes human factors, lowers workplace hazards, and lowers labor expenses. They help transport large or heavy objects from one place to another. To move objects, a conveyer belt may make use of "a belt, wheels, rollers, or a chain" [7]. A belt is generally extended across two or even more pulleys in conveyors. To allow for continuous rotation, the belt creates a closed circuit well around pulleys. One pulley, referred to as the driving pulley, hoists or moves the belt that transports objects from one place to some other [8]. "The drive pulley and belt" are powered by a rotor in most conveyor system configurations. The friction among contact objects keeps the belt fastened to the rotor. The driving pulley and idler must rotate in the very same manner, either right to left or left to right, for the belt to travel efficiently [9]. Although typical conveyor systems, like those seen in moving platforms and supermarkets, are straight, there are occasions when the unit must turn to transport the items to their intended position. Distinctive cone-shaped tires or rotors are used for the curves so that the belt may follow a curve or twist without becoming tangled [10]. Conveyors are "automated transportation systems" that move cargo along a predetermined path from one location to another. Inappropriate conveyor choices will raise production turnaround time and nonvalue-adding period in excess. A fabrication organization must use an effective conveyor to efficiently handle materials from one division to another to eliminate these timeframes [11]. The right choice of a conveyor is influenced by several variables, including the conveyor's pace, the weight and shape of the item to be conveyed, and the range to be covered. " Chain conveyors, screw conveyors, roller conveyors, belt conveyors, and others" are some of the most common conveyor systems used in many sectors [12]. This article's primary goal is to provide the top conveyor-picking choices and to offer a preferences-ranked list for such MHE options. "The conveyor selection problem" is initially resolved using four choices and six parameters.

2. MATERIALS AND METHODS

The "grey system concept" is a method for looking at ambiguity that excels at mathematically evaluating systems with hazy insights. According to "the grey system notion," a white system appears to include all the readily available information whereas a black scheme appears to get all the doubtful wisdom [13]. "A grey system" is one that only has the least part of recognized details. " Grey relational analysis (GRA), grey decision, grey programming, and grey control" are the main parts of the grey systems approach. GRA is part of the grey systems approach, which helps tackle challenges with intricate interconnections between various components and quantities [14]. Therefore, the GRA technique has been extensively employed to address uncertainty issues arising from discontinuous data and partial knowledge. Additionally, the GRA approach is one of the most widely used techniques for examining numerous associations between discrete data collections and for making conclusions when dealing with several attributes. The main benefits of the GRA technique are that it is some of the best ways to make judgments in a corporate context, the computations are easy to understand, and the conclusions are dependent on the raw data [15]. Widespread use of "Deng's (1982) grey systems approach" in a variety of domains. It has been demonstrated to be practical for coping with “inaccurate, insufficient, and ambiguous info”. "Grey relational analysis (GRA) is a branch of the grey systems approach”, which can be used to solve issues involving complex interactions between several different elements and elements [16]. Numerous MADM issues, including "hiring decisions (Olson & Wu, 2006), restoration planning for power distribution systems (Chen, 2005), an inspection of integrated circuit marking processes (Jiang, Tasi, & Wang, 2002), modelling of quality function deployment (Wu, 2002), defect detection in silicon wafer slicing (Lin et al., 2006)", etc., have been effectively addressed using GRA [17]. By incorporating all the achievement similarity measures considered for each option into a fixed value, GRA can help address MADM troubles. As a result, the original issue is reduced to a judgement issue involving a single attribute. As a result, following the GRA procedure, solutions with numerous characteristics can be simply evaluated [18]. Furthermore, a comparison sequence is created by converting the behavior of each possibility into the primary step of GRA. The term "grey relational generating" refers to this phase. Based on those sequences, "a standard sequence (ideal target sequence)" is determined. Finally, “the grey relational correlation between all similarity variants and the benchmark pattern” is determined [19]. "The grey relational grade" between each comparable pattern and the benchmark pattern is then generated based on those "grey relational coefficients". The optimal variant is the one whose converted comparable sequence has “the greatest grey relational grade among the reference sequence and itself" [20].

Step 1. “Design of decision matrix and weight matrix”

For “an MCDM problem” consisting of “m alternatives and n criteria, let $D = x_{ij}$ be a decision matrix, where $x_{ij} \in R$”

$$D = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad 1$$

Step 2. “Normalization of decision matrix”

Formulae 2 and 3 are used, respectively, to analyze whether normalizing two data sets is better whenever the higher type is assessed or stronger when the lesser type is. The information after normalization varies from zero to one.

$$M_{ij} = \frac{N_{ij} - \min(N_{ij})}{\max(N_{ij}) - \min(N_{ij})} \quad 2$$

$$M_{ij} = \frac{\max(N_{ij}) - N_{ij}}{\max(N_{ij}) - \min(N_{ij})} \quad 3$$

Where $i, j = 1,2,3, \cdots, n$

Step 3. "$Deviation = the \max value\ after\ normalization - value\ of\ the\ current\ row$" 4

Step 4. Computation of "Gray relation coefficient"

$$C_{ij} = \frac{\Delta_{min} - \xi\Delta_{max}}{Current\ value - \xi\Delta_{max}}, where\ zeta\ (\xi)\ is\ distinguishing\ coefficient \quad 5$$

Step 5. Computation of "Gray relation grade"

It represents the Gray Relation Coefficient on averages. After that, options are ordered using the "Gray Relation Coefficient's average" [21,22]. This article's primary goal is to provide the top conveyor-picking choices and to offer a preferences-ranked list for such MHE options. " The conveyor selection problem" is initially resolved using four choices and six parameters. Six evaluation criteria are "Fixed cost (FC) in €/h, Variable cost (VC) in €/h, Speed of conveyor (S) in m/min, Item width (IWI) in cm, Item weight (IWE) in kg and Flexibility (F)". Here "Speed of conveyor, Item width, Item weight and Flexibility" is beneficial criteria. "Fixed cost, Variable cost" are non-beneficial criteria.

3. ANALYSIS AND DISCUSSION

TABLE 1. Quantitative data for the alternate conveyors

Alternatives	S	IWI	IWE	F	FC	VC
C1	10	8.5	5	7	1.75	0.425
C2	11	11	5	9	2.075	0.425
C3	9	16.5	10	9	2	0.44
C4	8	14	7.5	7	2.15	0.44

Table 1 shows "the initial decision matrix for the conveyor selection problem". Here we consider four conveyors "Conveyor 1 (C1), Conveyor 2 (C2), Conveyor 3 (C3) and Conveyor 4 (C4)" as alternates. After consideration, "Fixed cost (FC) in €/h, Variable cost (VC) in €/h, Speed of conveyor (S) in m/min, Item width (IWI) in cm, Item weight (IWE) in kg and Flexibility (F)". Here "Speed of conveyor, Item width, Item weight and Flexibility" is beneficial criteria. "Fixed cost, Variable cost" are non-beneficial criteria.

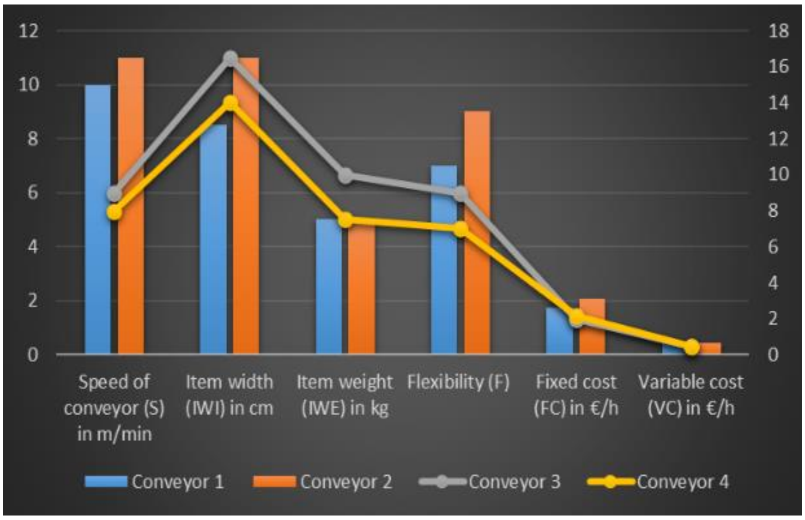

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Figure 1 illustrates "the initial decision matrix for the conveyor selection problem". Here we consider four conveyors "Conveyor 1 (C1), Conveyor 2 (C2), Conveyor 3 (C3) and Conveyor 4 (C4)" as alternates. After consideration, "Fixed cost (FC) in €/h, Variable cost (VC) in €/h, Speed of conveyor (S) in m/min, Item width (IWI) in cm, Item weight (IWE) in kg and Flexibility (F)". Here "Speed of conveyor, Item width, Item weight and Flexibility" is beneficial criteria. "Fixed cost, Variable cost" are non-beneficial criteria.

TABLE 2. Normalized matrix

0.6667	0.0000	0.0000	0.0000	1.0000	1.0000
1.0000	0.3125	0.0000	1.0000	0.1875	1.0000
0.3333	1.0000	1.0000	1.0000	0.3750	0.0000
0.0000	0.6875	0.5000	0.0000	0.0000	0.0000

Table 2 shows the normalized array for material properties of alternative conveyors. This is calculated using equation 2 for beneficial criteria ("Speed of conveyor, Item width, Item weight and Flexibility") and equation 3 for non-beneficial criteria ("Fixed cost, Variable cost").

TABLE 3. Deviation sequence

0.3333	1.0000	1.0000	1.0000	0.0000	0.0000
0.0000	0.6875	1.0000	0.0000	0.8125	0.0000
0.6667	0.0000	0.0000	0.0000	0.6250	1.0000
1.0000	0.3125	0.5000	1.0000	1.0000	1.0000

Table 3 shows the Deviation sequence matrix for the conveyor selection problem. This value is calculated using equation 4, that is Maximum value of the column of normalized value is subtracted from the current value of the normalized matrix.

TABLE 4. Grey Relation Coefficient

0.6000	0.3333	0.3333	0.3333	1.0000	1.0000
1.0000	0.4211	0.3333	1.0000	0.3810	1.0000
0.4286	1.0000	1.0000	1.0000	0.4444	0.3333
0.3333	0.6154	0.5000	0.3333	0.3333	0.3333

Table 4 shows the Grey Relation Coefficient matrix for the conveyor selection problem. This value is calculated using equation 5 and the zeta value is 0.5. Table 3 Deviation sequence matrix is for calculating the "Grey Relation Coefficient".

TABLE 5. GRG

Alternatives	**GRG**
Conveyor 1	0.6000
Conveyor 2	0.6892
Conveyor 3	0.7011
Conveyor 4	0.4081

Table 5 shows the Grey Relation Grade value for alternate conveyors. Its average values of "the Grey Relation Coefficient" using table 4. Here "Grey Relation Grade value for Conveyor 1 is 0.6, Conveyor 2 is 0.6892, Conveyor 3 is 0.7011 and Conveyor 4 is 0.4081".

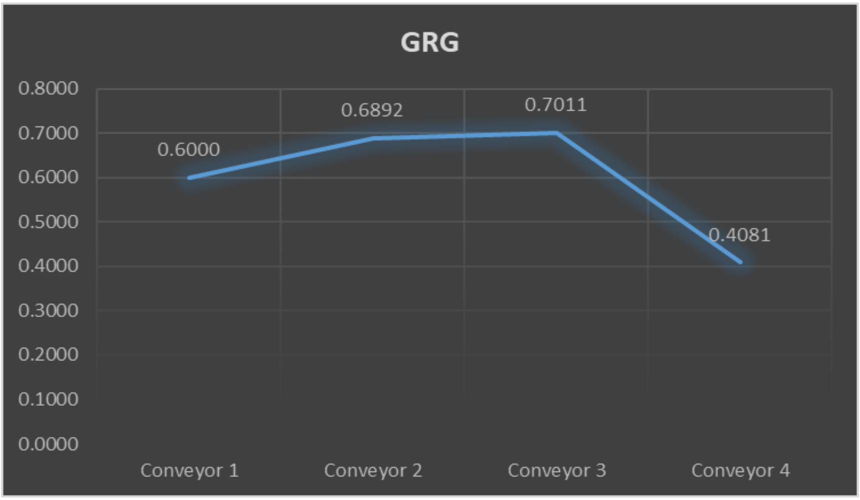

FIGURE 2. Grey Relation Grade

Figure 2 shows the graphical representation of the Grey Relation Grade value for alternate conveyors. Its average values of "the Grey Relation Coefficient" using table 4. Here "Grey Relation Grade value for Conveyor 1 is 0.6, Conveyor 2 is 0.6892, Conveyor 3 is 0.7011 and Conveyor 4 is 0.4081".

TABLE 6. The rank

Alternatives	Rank
Conveyor 1	3
Conveyor 2	2
Conveyor 3	1
Conveyor 4	4

Table 5 shows the rank of the alternate materials taken for this paper by ranking Grey Relation Grade values using table 5. Here rank for Conveyor 1 is third, Conveyor 2 is second, Conveyor 3 is first, and Conveyor 4 is fourth. The ranking order is “C3 > C2 > C1 > C4”.

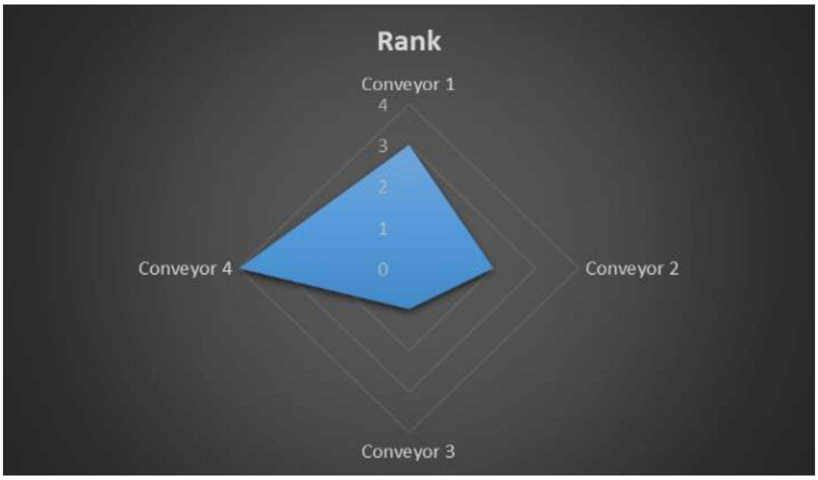

FIGURE 3. The rank of alternate materials

Figure 3 shows a graphical representation of the alternate materials taken for this paper by ranking Grey Relation Grade values using table 5. Here rank for Conveyor 1 is third, Conveyor 2 is second, Conveyor 3 is first, and Conveyor 4 is fourth. The ranking order is “C3 > C2 > C1 > C4”. Conveyor 3 was discovered to be the best conveyor among the selected alternate conveyors, as per the Grey Relational Analysis (GRA) technique.

4. CONCLUSION

The number of MHE kinds, such as "hand carts, fork trucks, automated-guided vehicles, conveyors, robots, automated storage and retrieval systems", computerized picking devices, etc., has increased dramatically in subsequent years. In a manufacturing business, the MHE could be used in a variety of settings, including exporting, and importing, production, arrangement, storage, etc. Limits placed by the site and resources, various conflicting specific designs, “unpredictability in the operational area, and the broad variety of machinery kinds and models accessible” are the main causes of the adoption model process' intricacy. Due to these factors, both concrete (such as "load capacity, energy consumption, cost, etc.") and qualitative (such as "flexibility, reliability, performance", etc.) factors must be considered by the decision-makers (DM). Therefore, in the existence of numerous analyses and qualitative factors, MHE selection is seen as "a multiple criteria decision making (MCDM) problem". Additionally, selecting MHE is heavily influenced by the DM's choices due to the ambiguity in the operating situation. Furthermore, it is exceedingly challenging to create a specific condition that may exactly express why one option is preferred more than another. The rank for “Conveyor 1 is third, Conveyor 2 is second, Conveyor 3 is first, Conveyor 4 is fourth”. The ranking order is “C3 > C2 > C1 > C4”. “Conveyor 3 was discovered to be the best conveyor” among the selected alternate conveyors, as per “the Grey Relational Analysis (GRA) technique”.

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