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Comparative Classification Algorithms for the Analysis of the Value of Information Flow for Decision Making in Small Manufacturing Companies of Developing Countries

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Abstract:-Performance improvement which is a daily activity for Small and Medium Size companies in the manufacturing sector, always depends on the good management of information flow for a better decision-making to facilitate shop floor operations that will have a major impact on quality and timely product delivered to customers. Decision-making in production companies always depend on the information that one received. This paper uses the characteristics of information flow (CIF) to predict a machine learning model of the value of information flow (VIF) that will facilitate decision-making of the shop floor operations carried by operators (machine, humans and computers). The compared machine learning model proved that: Gradient Boosting (GB) Model is the best model to predict the VIF as long as the characteristics are binary data or scale data with a score of 0.986, the mean squared error of 0.0098, the sensitivity of 1, the precision of 0.9821, and the specificity of 0.99951.

Keywords*: *Decision-making. Developing countries. Information flow Characteristics. Machine Learning. Management of information flow. Shop floor operations.

1. INTRODUCTION

Customer's satisfaction based on continuous product quality and timely delivery has always facilitate the improvement of performances in Small and Medium Size Enterprises (SMEs) which is a condition for sustainable development. Performance amelioration has always been at the center of scientific research and many researchers demonstrated that performance improvement is a function of information sharing and decision-making. The management of information flow (MIF) moves towards digitalize information known as information of things and it is a key for performance improvement **[1,2]**, but in some developing countries the concept of internet of things applied to the MIF is still not yet a mere event due to the lack of technology transfer and the random economic situation **[3-5]** . It is then an opportunity to work over a progressive transition from the traditional MIF in shop floor operations to the digital MIF. A proper MIF renders manufacturing companies continuously efficient when stochastics and none stochastics event related to machines and operators behaviors occur **[6-8]**. This paper focus on shop floor of manufacturing companies in developing countries which are moving towards a digitalize MIF but in which we still have some lacks that result to poor decision making when facing operations productions and later cause a decrease of performance of the company. A good MIF is also based on the analysis of information flow characteristics, according to **Mbakop et al. [9]** and presented by figure 1 and 8 (**Appendix** section) , the MIF consist of giving to information flow a value in order to facilitate decision making in shop floor operations for performance improvement of companies **[10]**. The impact of information flow on decision making by shop floor operators (machines, computers, humans) is visible and has to be considered.

The various works that analyzed the VIF in shop floor were based on the quality of information that is characterized by accessibility, transparency, timeliness and granularity **[11, 12]**. Some considered that VIF can be created by an information, which is transmitted correctly, Complete and in a timely manner **[18, 19],** by avoiding disturbances and media disruptions.

Considering the works of **Tomanek and Schröder 2016 [13],** the value of information flow is function of scale of the dimension of information flow, that value can also be influenced by the presence of materials on a production line in shop floor. The VIF can be deducted from the impact that materials undergo on shop floor, and the VIF can be determined by knowing the digitalization degree in a context of industry 4.0 using the method of Value-Added Heat Map (VAHM). From the works of **[10,31],** the value of information flow was then, the estimate function of the digitalization degree, in their works, the layout-specific digitalization degree indicates which percentage the degree of information flow promotes added value. The added value is computed from the ration of the sum of each information transfer multiplied with the corresponding value-added level and the amount of transferred information per time unit multiplied with the highest possible value added level.

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The resent works of **Mbakop et al. [32]** analyzed the value of information flow predictively based on artificial neural network(ANN) that where behaving as deep learning model because. The ANN model was trained with particular swarms optimizer (PSO) and genetic algorithm(GA). The results obtained from the proposed model had good accuracy and the value of information flow that was obtained was in the unit interval. This VIF was used as a key performance indicator for performance improvement in decision-making.

Until now the only recent work that used all the characteristics of information flow to analyze the predictive VIF based on ANN model. We have not seen a research work in the literature that has analyzed the VIF with classification algorithms of machine learning. When information is binary it shows how information flow

Can easily be understood by machines and smart devices. This analysis model of information flow using machine learning algorithm could be for a great help of managers of new digitalized companies of developing countries.

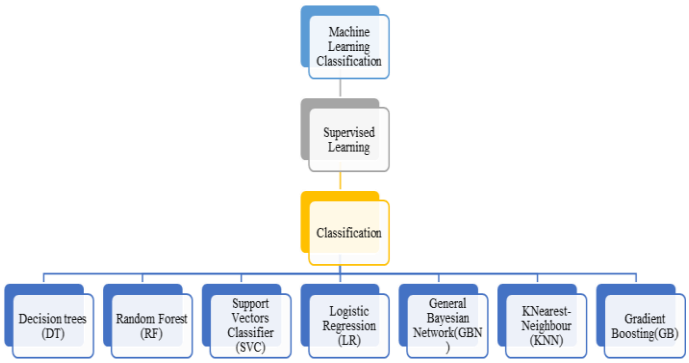

Figure 2 Classification of algorithms of supervised

It is therefore important to bring out a way of analyzing the value of information flow in shop floor of developing countries considering the decision-making and the characteristics of information. Having many characteristics of information flow that signify many data, the method of Value-Added Heat Map will no more be helpful unless we consider a reduction of variables. This is the reason for which our analysis is based on machine learning methods. This paper aims at integrating the CIF in the determination of the VIF to facilitate decision making by operators in the shop floor process using the approach of machine learning, by taken in consideration the hypothesis, that some of the CIF can be scale according to **Tomanek and Schroder [13, 31]** . The accomplishment of this gold lead us to related works on the determination of the VIF and Machine Learning Classification Algorithms Techniques, then a proposal methodology for the analysis of the VIF and a comparative analysis of the Machine Learning Classification Algorithms such as Decision Trees, Gradient Boosting, KNN, Support Vectors Classifiers, Logistic Regression, Random Forest, and Gaussian Networks Bayesian.

2. MACHINE LEARNING CLASSIFICATION ALGORITHMS

The analysis of the VIF in shop floor of developing using a machine learning algorithm approach has not yet been a studies focus according to article that we have read in the literature, because the development of information characteristics has been updated by **[9]**.

Machine Learning Methods have been used in many applications in industries, we will the present a briefly view of machine learning techniques and their different roles. Researchers have characterized machine learning in trees groups, namely: Supervised Learning, Unsupervised Learning, Reinforcement Learning. In this paper we will be concerned by supervised learning, among supervised learning algorithms as presented by Figure 2:

Support Vectors (SVC) is an algorithm of ML technique use for classification and prediction analysis due to its high accuracy which is based on statistical analysis, it has been developed for pattern recognition, classification, it uses a great number of data **[14-17],** it objective relies on is the individualization of hyper planes parallel to error minimization.

Decision Tree (DT) is an algorithm of ML with is also used for classification and prediction analysis. The main purpose are to expose the structural information contained in data, his network is formed of nodes that represents features (inputs) and the leaf nodes which represent the output **[18-19].**

Logistic regression (LR) : this is a classification function that uses class for building and uses a single multinomial logistic regression model with a single estimator , it is also used for prediction and it is usually states where boundary are between 0 and 1 **[20-21]**.

Bayesian Networks (BN): It is statistical classifiers that predict the class of probability, Bayesian networks are graphical models, showing the relationship between the subset of attributes and BN have exhibited high accuracy and speed when applied to large databases **[20-23].**

Random Forest (RF): this classification algorithm contains of a set of trees, in which similar independent vector vectors are distributed, and every tree issues a voting unit for the most common category in input **[24-26]**.

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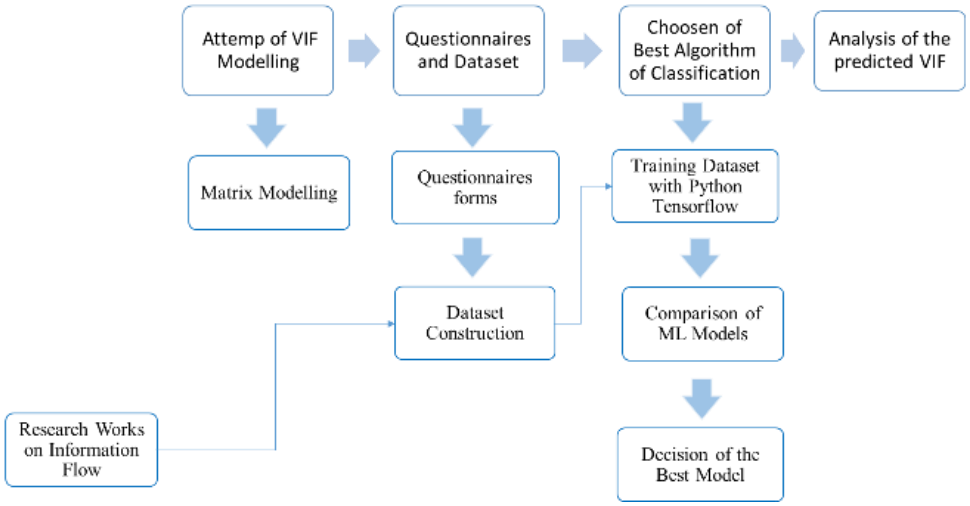

Figure 3 Method of determination or prediction of the VIF with Machine learning algorithms

KNearest-Neighbour (K-NN): KNN is an algorithm mostly used for classification problems and pattern recognition, this method classifies cases based on the relationship between variables and can be used for both classification and regression **[27-28].**

Gradient Boosting (GB): Is a machine-learning algorithm formed of weak learners as DT to build up a strong learner; it has a peculiarity cost function optimization **[29-30].**

3. METHODOLOGY

To bring out a new approach that will be lightly based on the previous one technique (VAHM) and for the characteristics of information flow to be integrated in the analysis, we will be using the different steps to predict the VIF using Machine Learning Algorithms. In shop floor of developing countries, IFC can have an impact on the production or manufacturing based on decision making by operators. The proposed methodology is presented by fig.3. We will first of all modelling the information flow based on information characteristics, then we will make use of the questionnaires form fig. 4 (Appendix section) and with some considerations of the research works information flow, to construct the dataset of features and output that will help us to build the machine learning model and then the software python Tensorflow will be used to split and train the dataset, to compare the different model of ML by given each accuracy of ML model then chose the one that has the best accuracy and lastly interpret some predicted pertinent VIF.

For dataset acquisition we carried out a survey, in which we submit to employee an online answer sheet question concerning, the importance of each characteristics of information flow on the value of information flow and that will be later be exploited to have the correlation matrix of the information flow. For the sample questionnaire kindly have a look in appendix. A simple mathematical modelling of the VIF will be developed depending on the results of survey and the various characteristics of information flow. The comparative analysis of VIF will be a way of chosen the suitable model analysis for paper.

3.1 Presentation of an information flow function of its characteristics

From de definition of the characteristics of information flow that constitute an information flow (IF) The IF is a row matrix M_{IF} of 5 rows Matrix (X_k, $1 \leq k \leq 5$) representing all the 5 matrix of the IFC and all the IFC are not dependent each other. Each of X_k row matrix has a x_i component that is binary for one case and for an order one only the dimension information value will not be binary data but they will derive from the scale of information dimension as presented in Table 2.

For each $X_k = (x_i)$,

$$x_i = \begin{cases} for\ Type\ , 1 \leq i \leq 2 \\ for\ Dimension\ , 1 \leq i \leq 6 \\ for\ Direction\ , 1 \leq i \leq 4 \\ for\ Parameters\ \ 1 \leq i \leq 4 \\ for\ Quality,\ \ 1 \leq i \leq 4 \end{cases} \quad (1)$$

An information flow shared in a shop floor or organization for services or product manufacturing or delivery has the following Matrix given by eq (2).

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$M_{IF} = (X_1, X_2, X_3, X_4, X_5)$ (2)

For quality, we will not consider the fifth sub characteristics, which is the cost of information flow in this paper that is why quality contain 4 components.

The VIF that we want to obtain or predict for every information flow arriving in the system is described by eq (3), is presented by figure 7.

$$VIF = f(X_k) \quad (3)$$

The VIF is then a function of X_k, determine the function mathematically will be a fastidious work because we have a lot of inputs and just one output, to avoid it. In order to have a suitable model we will used the data coming from the audit and from the results of some researchers in order to have the input and the output of the system which will enable the an easy analysis.

3.2 Questionnaire and Dataset collection

Questionnaires were built and submitted to industries of some developing countries, according to figure 4 (**Appendix Section**), the objective of the questionnaire is to have a general view on the influence of information flow characteristics on decision-making and performance, which is, illustrate by the value of information flow. Questions sample were like: Tick the sub-characteristics of the dimension of information flow that can have influence on the value of information flow, from your above response do we have a good or a bad value of information flow? The obtained dataset could not be analyzed by the VAHM, but because that are voluminous that is why the choose of Machine learning methods. From these questionnaires two dataset 1 and 2, will be generated, the first one will consider the responses of the questionnaires and the second one with considered the dataset 1 and the scale value of dimension of information flow proposed by **[11, 31]**.

3.3 Comparative Analysis of Machine Learning algorithms

The comparative analysis will be based on the score and metrics of the classification algorithms models given by eq (4). The performance analysis of these algorithms of classifications will be focused on the loss function criteria such as the percentage of the True Positive (TP), the False Positive (FP), the True Negative (TN) and the False Negative (FN) given by eq (5)-(17).

With y' the predicted and y the actual VIF, N is the number of samples.

(9), $MSE = \sum_{i=1}^{N} \frac{(y'_i - y_i)^2}{N}$ (10), $\%TP = \frac{TP}{FP+TP}$

(11), $\%FP = \frac{FN}{TP+FN}$ (12), $\% TN = \frac{TN}{TN+FP}$

(13), $\% FN = \frac{FP}{FP+TN}$ The Precision $= \frac{FP}{FP+TN}$ (14),

The sensitivity $= \frac{TP}{TP+FN}$ (16),

Specificity $= \frac{TN}{FP+TN}$ (17).

Among all these parameters, there is the AUC (Area under the Curve) and the ROC (Receiver Operating Characteristic.

4. RESULTS AND DISCUSSION

Accuracy $= \frac{TP+TN}{TP+FP+TN+FN}$ (15),

4.1 Heat Map of information flow describe by the correlation matrix when having binary data

When the CIF are binary or except the dimension, which is not binary, from the data collected in a sharing of an information flow based of its characteristics in shop floor of developing countries.

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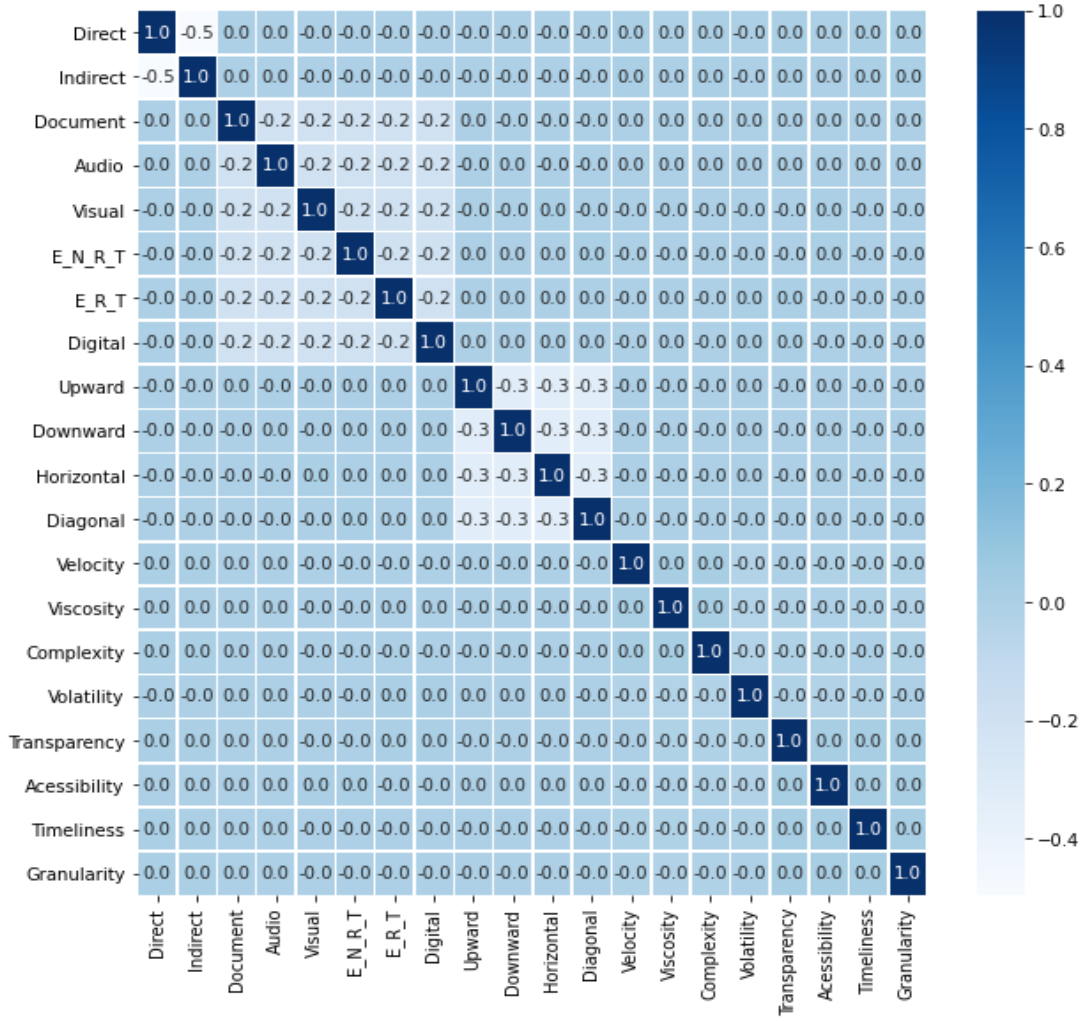

Figure 5 Correlation Matrix of the CIF

It happens that the correlation matrix is the same and its shows the relationship or the dependency between the CIF as presented by figure 5.

The correlation Matrix for the two cases indicates the following observations

Observation 1: A perfect dependency (1.0) of every characteristics of information flow with each other, which mean technically that, the information flow sharing depends on the CIF.

Observation 2 : -0.5 (absolute value 0.5) between each of the sub characteristic of the type of information flow , namely direct and indirect indicates that one of indirect or direct information has to increase in the production chain when another decreases , it is very accurate for it isn't obvious to carry out maintenance operations when production operation are going on.

Observation 3: A negative dependency (-0.2) indicates between each of the sub characteristic of the dimension of information flow a light independency between each of the sub characteristics , when digital is present , each of the other dimension has to be absent , it confirm the assumption made in hypothesis 2.

Observation 4

A negative dependency (-0.3) between each of the sub characteristic of the direction of information flow, which signify to avoid confusion in decision making by operators in shop floor an information flow may not come from two level of decision making, but even if it is the case the influence of dependency is less than 0.5, so it will not have a lot of effect on the value of information flow as long as we have binary data.

Observation 5

From observations 2, 3, and 4, the influence of levels of decision making is more than the one of the dimension of information flow looking at the absolute value of dependency coefficient, the types of information flow (direct or indirect) has a great negative influence more than an information that comes from the decision level and also the transmission support (dimension) of information. From all the above

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observations, it does not exist a total dependency between the features or information flow characteristics, therefore we cannot use this dataset for regression algorithms but only for classification algorithms as long as machine Learning is concerned. We will try to determine the function f of eq. (8) that helps to give out the VIF (having binary data) by processing a simple analysis of the VIF by considering hypothesis.

4.2 Simple VIF analysis without Machine Learning Methods.

From the above observations and literature remark, it comes that the influence of the majority of the sub characteristics of IF on VIF (binary data), except complexity, transparency and granularity of information which depend to the comprehension level, the knowledge (humans) or the performance (machines) receiving the information to make a decision. However, we cannot directly confirm the influence of dimension and direction on the VIF because we have a voluminous dataset. The following hypothesis help us to construct a mathematical modelling: **Hypothesis 1:** An information flow starts the production process and it has to be condition by the characteristics direct or indirect, in this paper, we consider that direct and indirect are binary data.

Hypothesis 2: An information flow cannot be shared without a dimension or medium, an operator, if there is no medium the information value is 0, this is the case of industries where there is a poor consideration of MIF.

Hypothesis 3: We consider that the dimension of information flow do not have the same influence, as presented in table 2, this the case where information medium do not have the same weight, which is the case of industry that aims at being 4.0.

Hypothesis 4: An information flow depends on direction of information, which can be coming from a machine 1, from an operator, and from a computer. In this paper, an information flow has to come from one direction only and then the direction will be 1 and the rest 0. This is the case of industry moving to industry 4.0.

Hypothesis 5: An information flow has to be accessible, timely, it must have a good velocity, and it should have any velocity, neither volatility.

From hypothesis, H1, H2, H4, and H5 (dataset1) we notice that the VIF obtained from the dataset is given by eq (16):

$$VIF = 1 \ if \begin{cases} H1 \\ H2 \\ H4 \\ H5 \end{cases}, \ 0 \ else \qquad (18)$$

From hypothesis, H1, H3, H4, and H5 (dataset 2) we notice that the VIF obtained from the dataset is given by eq (19):

$$VIF = 1 \ if \begin{cases} H1 \\ H3 \\ H4 \\ H5 \end{cases}, \ 0 \ else \qquad (19)$$

The f function that we tried to determine is depending on the hypothesis of eq (18), (19). These do not allow us to determine easily and speedily the value of information flow in order to present the different characteristics, which can be excluded in order to have good information value. Looking the voluminous data, it is important to use the machine learning Model algorithms from classification to choose the best algorithms for the comparison analysis of the value of information flow for case 1 and case 2.

4.3 Comparison of Machine Learning Models: Classification Algorithms

In this paper, we will be focus on these various classifications algorithms: DT, KNN, RF, SVC, LR, GNB, and GB. After splitting and train the dataset, the results obtained from our computation with python enable us to be focus on performance metrics. The splitter percentage of dataset 1 and 2 was as follow: 80 percent for the training and 20 percent for the prediction.

Training Performance of Models evaluation of dataset 1 and 2

The training scores of the classification ML models are presented in Table 3 and 4 for dataset 1 and 2 respectively.

Table 3. Training performance of ML models dataset1

	ML Classification Models						
Names	KNN	SVC	LR	DT	GBN	RF	GB
Scores	0.98	0.9975	0.9975	0.9957	0.9975	0.9963	0.9975

Table 4. Training performance of ML models dataset 2

	ML Classification Models						
Names	KNN	SVC	LR	DT	GBN	RF	GB
Scores	0.9785	0.9871	0.9794	1,00	0.9576	0.9972	0.9917

From table 3 and 4, all the ML models have been well trained, but DT has an excellent learning abilities in the dependencies that exist between the VIF and the characteristics of information flow when we have mixed data it is a justification of an excellent score .

To choose the best model, the accuracy of each model will be an important aspect.

Predictive Performance of Models evaluation of dataset 1 and 2

The performance models evaluations based on algorithms metrics for both dataset 1 and 2 are given in table 4 and table 5 respectively.

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According to table 4, the predicted models are all accurate for the analysis of the information flow. But looking at accuracy, the precision and the sensitivity, the best algorithm is the Gradient Boosting Model (GB) for case 1 with an accuracy of 0.998043 and MSE = 0.00204 with a precision and a sensitivity of 0.997 and 1 respectively ; Nevertheless SVC, LR, GBN are also suitable algorithms with almost the same accuracy and same MAE. DT is also good for the prediction analysis of VIF for case 1 with an accuracy of 0.9976 but it is a weak learner when using only binary dataset.

Table 4. Performance models evaluation for dataset 1.

		Performance Metrics						
Identification	Names	Scores	MAE	MSE	Sensitivity	Precision	Specificity	ROC-AUC
1	KNN	0.9863	0.02599	0.02599	0.700	0.972	0.9984	0.995
2	SVC	0.998034	0.00204	0.00204	1	0.9754	0.9977	0.991
3	LR	0.998034	0.00204	0.00204	1	0.975	0.997	0.999
4	DT	0.997604	0.003071	0.003071	0.9848	0.775	0.9979	0.994
5	GBN	0.998034	0.00204	0.00204	1	0.975	0.9754	0.998
6	RF	0.997912	0.002866	0.002866	0.9924	0.975	0.9977	0.999
7	GB	0.998043	0.00204	0.00204	1	0.975	0.997	0.999

Table 5. Performance models evaluation for dataset 2.

ML Classification Models		Performance Metrics						
Identification	Names	Scores	MAE	MSE	Sensitivity	Precision	Specificity	ROC-AUC
1	KNN	0.9665	0.0235	0.0235	0.333	1	1	0.95
2	SVC	0.9860	0.0155	0.0155	0.999	0.9821	0.999	0.98
3	LR	0.9766	0.0023	0.0023	0.9369	1	1	0.9998
4	DT	0.9857	0.0016	0.0016	1	1	0.9618	1
5	GBN	0.9512	0.041	0.041	1	0.919	1	0.9809
6	RF	0.9807	0.0047	0.0047	0.9819	1	1	0.999
7	GB	0.9867	0.0098	0.0098	0.9909	0.9821	0.99951	0.999

From table 5, the suitable algorithm for this dataset 2 is GB with a score of 0.9867 with a precision and a specificity of 0.9821 and 0.999. Gradient Boosting is an algorithm of machine learning that is specialize in optimization of the loss function commencing by a weak learning method as DT to become later a strong later and a strong optimizer. The second model algorithm is SVC, as from table 4, so it can be used for both binary and none totally binary data. DT learn better than GB and SVC when having mixed data, both binary or not.

From table 4 and 5, it comes that the suitable model for the analysis of VIF in this paper is Gradient Boosting classifier, because it has an excellent score and learning method due to it optimization cost function. In a situation where information flow characteristics is binary data and when dimension are scale as in model of industry 4.0, Gradient Boosting algorithms will help the managers of the shop floor operations to select what information characteristics give a good VIF to enable decision making.

4.3 Interpretation of the prediction analysis

An information flow sharing between shop floor operators (humans and or machines) during operations processes can have a VIF that is considered or not according to the characteristics of the information flow. Depending on the kind of operators some, information characteristics can be illustrated by this example: An information flow can be complex for man operator but not for an automated machine , a paper information is more for a human operator than for machine or computer , Digital information is more suitable for interconnected machine than for humans , so whether an information flow is destined for a machine, human or computer each characteristics of information flow will correspond to each operator for a better interpretation for a better decision making , that is why figure 6 presents GB model in decision making.

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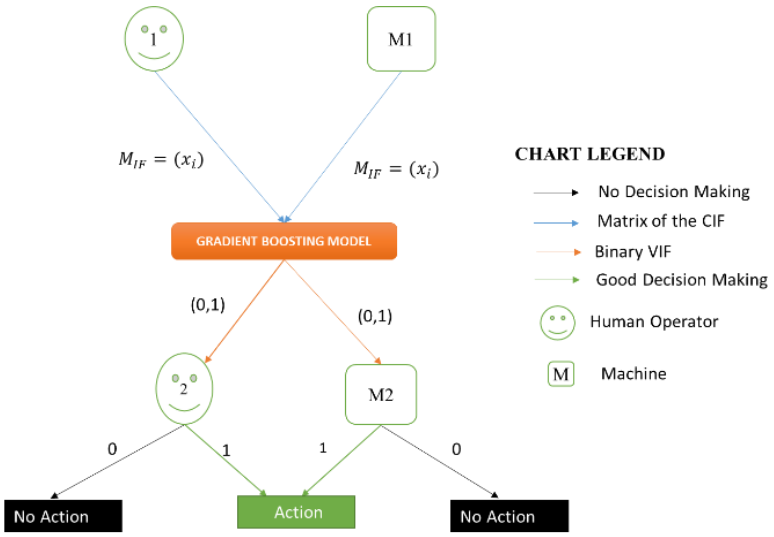

Figure 6 Illustration of the analysis of VIF with the GB model for decision making.

4.4 Prediction analysis based on the dimension of information flow dataset 1 and 2

With the GB model on dimension of information flow, it comes that:

GB1: An information flow should not derived from more than one medium; if not the value of information, flow will be 0. Concerning the document, the Audio, Visual, Electronic non-real time (E_N_R_T) information and the electronic real time information (E_R_T), the CIF can give out a good VIF if there is no loss of information (volatility , 1),or there is no delay (velocity 1 and timeliness 1) and that the human operator has to easily decode the complexity (0) of the information flow , the information flow has to be transparence (1) and well details or granular (1) , the information flow must not come from than one direction . in shop floor where is are still paper information, or audio, transparency of information , accessibility , granularity ,velocity , timeliness have to be maximized and volatility and complexity has to be minimized to zero.

GB2: Concerning digital information, the model gives out a good value of information flow when there aren't the disruptions that can occurs in the information sharing from the directions, and also from the network problems in the developing countries, this then can't allow machines to operate in their optimum performance level.

GB3: In this work the model shows us that, here the direction of information does not have a mere influence of the value of information flow except when the information is coming from more than one decision making level. It is not in all developing countries that directions of information have the same effect of information as in this work (where it represents a total independence decision making production operators with facilitate it performance for production), because of the presence of human personnel at the decision level of operations, the order from the tactical level or a supervisor may have indirectly a great influence on the human operator, consequently on his production action.

Conclusion

Information management in shop floor operations is at the center of decision-making and performance operations improvement, a well-organized MIF based on the CIF will increase the efficiency of the SMEs.

This article aimed at comparing machine learning (KNN, SVC, LR, DT, GBN, RF, GB) model to predict
the VIF in shop floor of SMSs in developing countries in order to improvement decision making by operators
or machine on operations tasks. It emerges from this research works that previous methods such as VAHM and Information process integration for the determination of VIF were used, but without integrating all the CIF. The recent work which integrated all the CIF only used ANN to analyze the VIF according to the specificity of developing countries where information flow is disorderly manage. A survey on the influence of the CIF on VIF has been carried out and it came from this survey that, the collected data were binary firstly and we added scale data for the dimension of information flow based on the results of **[11]**. A simple analysis model on the VIF was not accurate, that is why using the comparative ML algorithms, GB classifier was the best model that has been chosen for both cases with the following major performance metrics, score of 0.9867, the mean squared error of 0.0098, the sensitivity of 1, the precision of 0.9821, and the specificity of 0.99951.

Appendix

See Figs 1 , 4 and 8.

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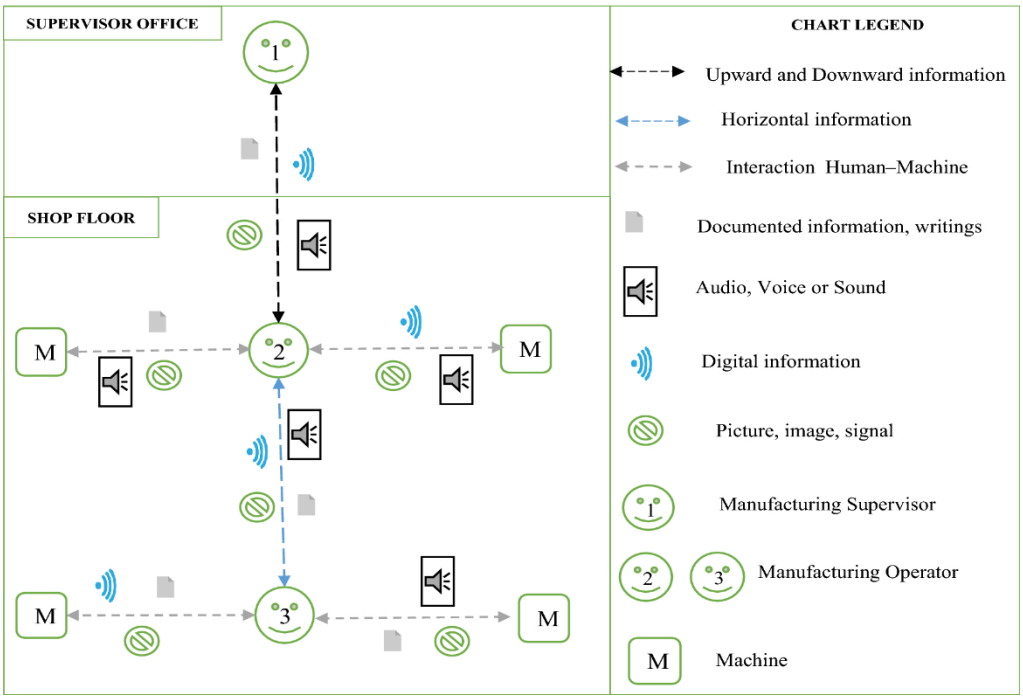

Fig.1 information flow sharing in Small-and Medium-Sized manufacturing companies of developing countries

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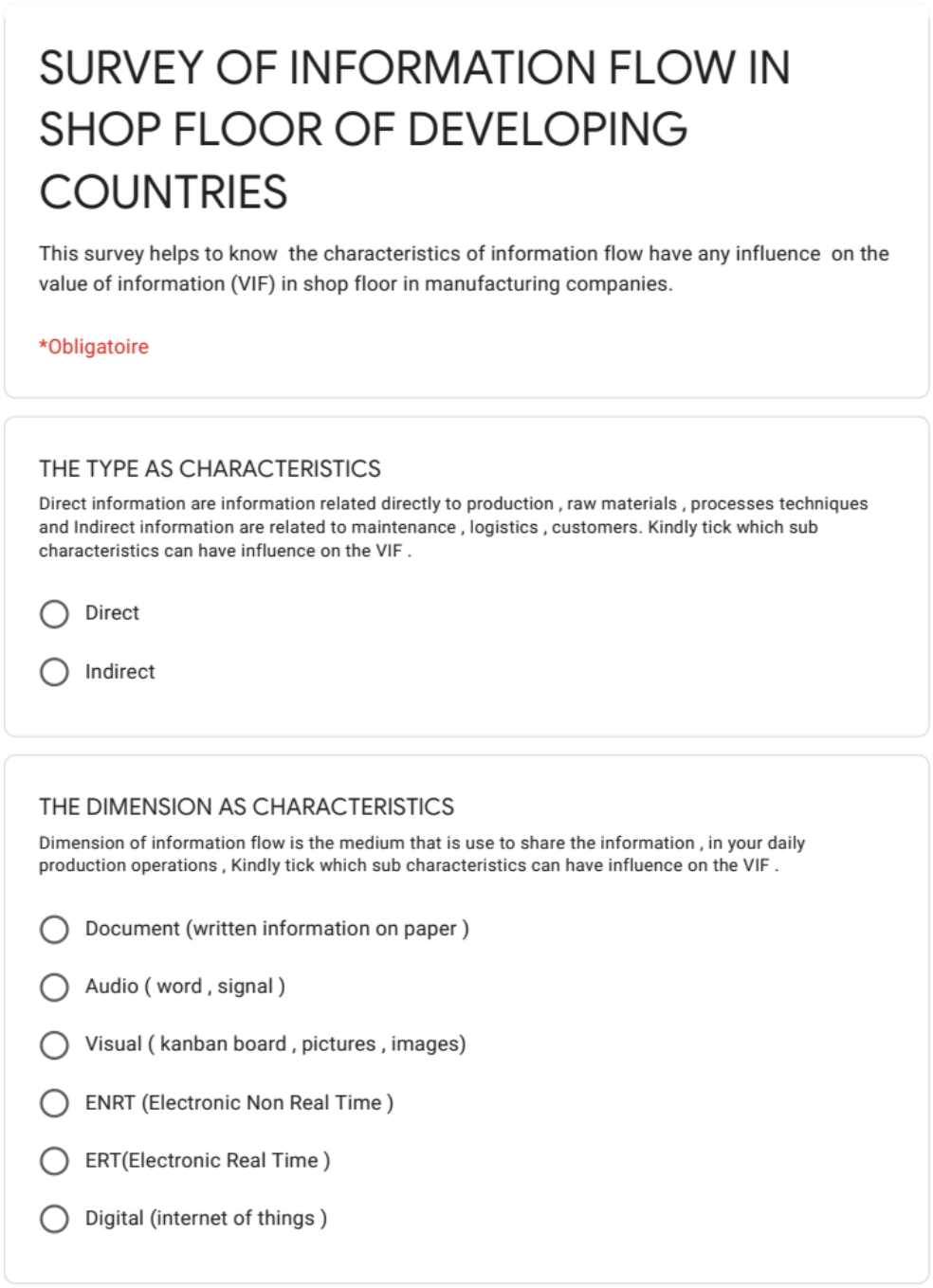

SURVEY OF INFORMATION FLOW IN SHOP FLOOR OF DEVELOPING COUNTRIES

This survey helps to know the characteristics of information flow have any influence on the value of information (VIF) in shop floor in manufacturing companies.

*Obligatoire

THE TYPE AS CHARACTERISTICS

Direct information are information related directly to production , raw materials , processes techniques and Indirect information are related to maintenance , logistics , customers. Kindly tick which sub characteristics can have influence on the VIF .

- ◯ Direct
- ◯ Indirect

THE DIMENSION AS CHARACTERISTICS

Dimension of information flow is the medium that is use to share the information , in your daily production operations , Kindly tick which sub characteristics can have influence on the VIF .

- ◯ Document (written information on paper)
- ◯ Audio (word , signal)
- ◯ Visual (kanban board , pictures , images)
- ◯ ENRT (Electronic Non Real Time)
- ◯ ERT(Electronic Real Time)
- ◯ Digital (internet of things)

Fig. 4 Extract of the survey form of the influence of the CIF on the VIF .

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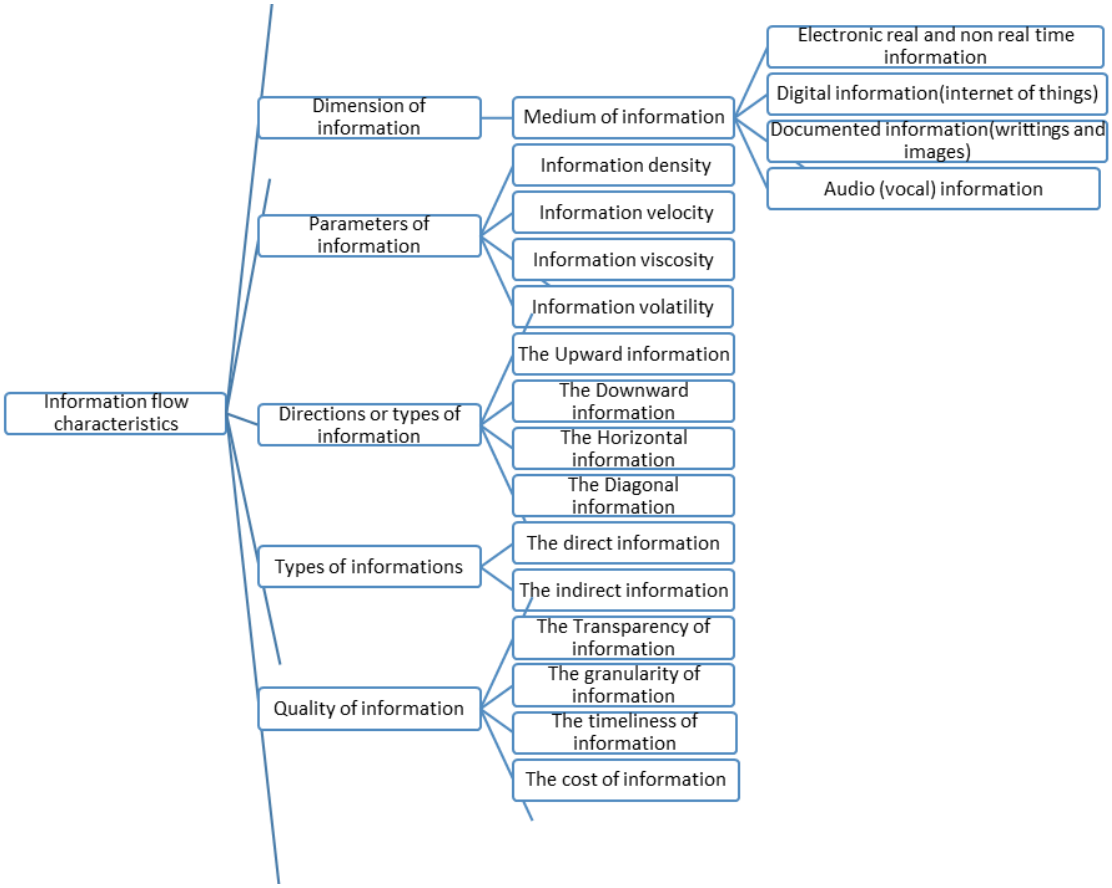

Fig. 8 General characterization of information flow

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