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ORIGINAL RESEARCH

Moving to a Flexible Shop Floor by Analyzing the Information Flow Coming from Levels of Decision on the Shop Floor of Developing Countries Using Artificial Neural Network: Cameroon, Case Study

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Abstract *Performance improvement in manufacturing is the major target of small and medium size enterprises (SMEs) of developing countries. This performance has always been linked to the good management of information flow (MIF) which is also a key to transforming a non-flexible shop floor to a flexible one. The MIF in developing countries has always been accurate when characterizing the information flow. The good MIF is always based on the value of information flow (VIF). In this paper, we analyze the influence of the direction (decision-making levels or information from hierarchy's offices) and also the dimension (medium) of information flow on VIF on the shop floor of developing countries, with Cameroon as a case study. The audit results obtained from shop floors show that, in developing countries such as Cameroon, there is still a great impact of the non-digital information flow in production operations, such as paper, audio, and visual information. The results also show that the collaboration between the personnel influences the production operations jobs on the shop floor as long as hierarchy's levels of decision making are concerned. From the results obtained, a proposed model of information sharing depending on the direction and the dimension in a woodworking company is presented with a decision flowchart based on the VIF. The analyzed VIF with artificial neural network shows that SMEs can become efficient by considering the visual information at every job post. A shop floor can only become flexible when it has a good VIF.*

Keywords Developing countries · Dimension · Direction · Flexible shop floor · Performance · Value of information flow

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Introduction

The economic growth in developing countries can be successful with the development of small and medium size companies especially in Cameroon. This development needs to pass through the timely delivery of good quality product and customer's satisfaction, which stand as production key performance which can also play a major role for the improvement of the economic growth in a country (Adam et al., 2020; Alam & AL-AMRI, 2020; Tran & Le, 2020). According to Wei Ng et al., 2014, Vilarinho et al. (2018), and Torres et al. (2020), some general root causes of the poor performance in shop floor are: The absence of the process standardization; the poor value of the Overall Equipment Efficiency (OEE); the lack of 5S implementation methods; the absence of Kaizen method known as continuous improvement and an ERP (Enterprise Resources Planning). These root causes always lead to poor quality product and delay in production. From the works of Dey et al. (2019); Shukla et al. (2019); Singh et al. (2019);

Contador et al. (2020); Evans and Bahrami (2020); Ojstersek et al. (2020) to improve company's shop floor performance, the production system of the shop floor has to be flexible when facing unpredictable evens related to operators availabilities, raw materials, machine breakdowns, environment constraints, customer's requirement, and markets competition. The transformation of a normal production system to a flexible production system, or to a flexible shop floor consists of setting up a good system of flow management (information and materials flow) in production or service operations (Closs et al., 2005; Dawaikat, 2017; Kaur et al., 2017; Wadhwa et al., 2009; Palanisamy, 2012). Thus, to improve the performance of the shop floor, one must focus also on the shop floor management of production, having as major objectives to ensure proper materials and information flow, and the identification of shortcomings in information flow sharing and the scheduling of operations and resources (Alcaide-Muñoz et al., 2018; Huo et al., 2016; Materna et al., 2019; Nakandala et al., 2017; Suprapto et al., 2017). These objectives produce as benefits in the shop floor, the increase of transparency and accessibility to data, the amelioration of shop floor communication, and the digitalization of the shop floor.

Each material to be processed on a production line has to be linked to an information describing the materials properties and the processes to be carried on by machines or operators. The management of production flow focuses then, on the management of information flow. Information flow management has for long been a concern in the research environment. In highly developed countries, the management of information flow focuses on the transition toward industry 4.0 as well as on development of new facilities to easily share the information flow as Internet of things (Mourtzis et al., 2019; Muller, 2017; Richter et al., 2017; Tomanek et al., 2020) by given a value to every shared information flow. However, in some developing countries, small manufacturing companies are still running their production operations in the traditional shop floor due to economic shortage and low transfer of technology policies (Agu & Mbah, 2013; Saymeh and Sabha 2014; UNIDO, 2021). Managing the information flow in developing countries has pushed us Mbakop, Voufo, et al. (2021) to present a general characterization of information flow such as the type, the dimension, the direction, the parameters, and the quality of information flow. The dimension of information presented can be paper, documented, audio, mouth to mouth, Kanban card, electronic, visual and digital information (Chi Anh & Matsui, 2011; Tezel et al., 2009; Meudt et al., 2017; Tomanek et al., 2016, 2020). Knowing that every information flow is coming from a sender to a receiver, it refers also to a motion of information in all the level of decision making in companies known as direction of information flow. The direction of information flow can also be known as the sense of flow of information (upward, downward, horizontal, and diagonal).

The value of information flow (VIF) has been determined by many researchers to ascertain and improve the shop floor performance using different methods and characteristics such as dimension and quality. The VIF obtained by Tomanek et al. (2020) based only on the dimension of information (medium) in a shop floor where: The digital information, the automated, the electronic, the visual and verbal, and the documented (writing) have 5/5, 4/, 3/5, 2/5, 1/5 as VIF, respectively. The work of Mbakop, Biyeme, et al. (2021) detailed the analysis of information flow based on its characteristics by given out a model, a quantification technique, and a predictive analysis system of performance of enterprises of developing countries. However, a deep emphasis was not focused on the combined influence of the dimension and the direction of information flow on the VIF. More often, researchers do not consider the weight that an information flow coming from a decision-making level related to the direction of information flow can have on the receiver of the information.

In many cases with developing countries, information (coming from a high level of decision) received by an operator is not questionable even if it does not have any added value to the production flow. Such information can be the wrong presentation of production steps or requirement by the production supervisor or errors in machining conditions and settings. According to Alcaide-Muñoz et al. (2018), Bangre (2018), Nowak et al. (2020), the information shared between employees is favorable for great improvement of shop floor performance referring to the horizontal information flow sharing. It is for this reason that this paper sets out to solving the problem of performance by analyzing the influence of direction and dimension on the sharing of information flow based on the VIF using an artificial neural networks (ANN) (developed by Mbakop, Biyeme et al. (2021)) with Cameroon shop floor as a case study. In simple terms, the goal of this paper is to make known to managers, to production supervisors, and production operators, the influence that the weight (how and where, how and to whom) of a shared information flow coming from a level of decision through a medium may have on shop floor performance when production operations are being carried out. The outcome of this work will enable managers of SMEs to improve their methods of information sharing by improving the performance of their shop floor even without being at the technology level of industry 4.0.

Review of the Analysis of the Value of Information Flow on the Shop Floor

The management of information flow on the shop floor for production operations is also based on the VIF that is shared between the operators (humans) or machines (flexible machines or traditional machines). To VIF on the shop floor, some researchers based their interest on the analysis of the integration of information flow in the process, some, on the analysis of the characteristics while others, the analysis of the quantification of Shannon theory. Talking about the integration of the information flow in the production process, Aubert et al. (2003) focused on the quality of information flow (accessibility, timeliness, transparency, and granularity) to analyze the value of information flow. In their analysis, they considered the quality of information flow as a cost function. The result of their analysis showed that, the more the quality of information flow was low, the more the value of information was low, and the more the value added to the production process was low. Berente and Vandenbosch (2004), still on the same integration of information flow in the production process, noticed that the cost function of the quality of information flow (QIF) was very difficult to evaluate. However, they rather used the time to measure the quality notion. To measure the time, they focused on these question: At what time an operator be it human or machine can determine the accessibility, the transparency, the timeliness, and the detailed information. They were forced to use audit method in order to have all the quality information time for the job operations that were in the shop floor. However, some researchers as Bateman et al. (2009) did not use the same approach as the previous researchers, but they analyzed the value of information flow based on visual management that are formed from information posted on boards. Their analysis of the value of information was to build up key performance indicators (KPI) for information present on boards. The results obtained proved that, visual information which is a part of dimension of information can improve the performance activities on the shop floor and enable a good communication between personnel. Still on KPI, Meudt et al. (2017) used the value stream information storage media like Paper, Employee (mouth to mouth communication), Kanban cards/FIFO, and CAD–CAM-Software Tool to evaluate the value of the information flow on the shop floor to reduce waste and improve quality production. The value of information in their research works was defined by the following KPI, DA (data availability), DU (data usage), and DR (data rate). Another approach was presented by Tomanek & Schroder (2017), these researchers used the value added heat map (VAHM) to analyze the value of information flow on the shop floor by focusing on the dimension of information flow. They carried out an audit on the shop floor as the implementation of their research methodology. The stream analysis of information using the VAHM demonstrated that digitalized information such as Internet of things has 5 as scale value and paper information has 1 as scale value. In this paper, the VIF will range from 0 to 1 to determine the amount of information or the capacity of the information flow that it takes for a medium system to enable the shop floor to be performant. Mourtzis et al. (2019) quantified the value of information flow with the Shannon Theory on information for a transition of traditional shop floor to shop floor of industry 4.0 based on the research work of Mourtzis et al. (2017). The Shannon Theory measures the quantity of information flow transferred through a medium of information at a source without focusing on who is the sender or the receiver. The Shannon Theory can also measure the entropy of information flow in a channel. The results they obtained show that, when the entropy of the information flow is null, the capacity of information transmission which defines also the value of information is 0. However, in their works, they have not valued the capacity of other dimensions such as paper information, audio information, and oral information because these dimensions of information also present the real environment shop floor information shared in developing countries. Tomanek et al. (2020) have equally analyzed the VIF going from their hypothesis (Tomanek and Schroder, 2017). The VIF was about computing the digitalization degree on the shop floor. They found that, the more the shop floor is digitalized, the higher the VIF shared. Mbakop, Biyeme, et al. (2021) did a predictive analysis of the VIF for developing countries, in their analysis they ranged the VIF in the unit interval. Mbakop, Biyeme, et al. (2021) consider that when VIF ≥ 0.5, the shop floor has the ability to improve its performance.

From the previous research works presented on the analysis of the VIF, it comes out that many researchers focused on dimensions of information (media) and the QIF. However, they did not consider in their analysis the direction of information flow which states the sense of flow of information. On shop floors of developing countries, when an information flow is sent from a supervisor to an operator, the influence of the message coming from a supervisor to an operator has a great impact. They did not integrate the influence of the information coming from a strong decision-making level operator to a lower decision-making operator. It will be of a great use to analyze a coupled influence of the complete dimension of information and the various direction of information in the value of information. Information flow on the shop floor can be characterized for a good management in production operations. Therefore, as described by Mbakop, Voufo, et al.

(2021), an information flow can have five characteristics which are made of sub-characteristics that will form a total of twenty components of dynamics vectors, when the information is shared for point A to point B. The dynamism of information flow is the consequence of using artificial neural network because of their high abilities to analyze dynamic data with a good score and their capacity of analyzing complex systems which are dynamic (Abdipoura et al., 2019; Çınar et al. 2020; Göppert et al., 2021; Hosseinzadeh et al., 2020; Thomas et al., 2017; Lingitz et al., 2018).

The structure of an ANN for regression having one output is illustrated by Fig. 1.

The ANN that will be used to analyze the influence of dimension on this information flow will be built as presented by Table 1 as inspired in the works of Mbakop, Biyeme, et al. (2021).

Methodology for the Analysis of the Impact of Dimension and Direction on the VIF

The proposed methodology that will lead to the result of this manuscript starts with the weight model of the VIF that will be used to determine the weight of the dimension and direction of information flow resulting from the audit data obtained. We will proceed with the construction of scenarios 1 and 2 based on hypothesis resulting from the audit. The various hypotheses depend on the characteristics of information flow characteristics (CIF) to facilitate the analysis of the audit data obtained. The next steps will be to use the formula of the weight of the CIF, to compute and present the weight of dimension and direction of information flow coming from the audit result, respectively. The analysis of the influence of the direction and the dimension of the information flow of scenarios 1 and 2 will follow to end up with a proposed relationship between the values of information flow with the flexibility of a shop floor (Fig. 2).

From the information flow characteristics, the value of information can be considered as the addition of the weighted values of other characteristics. We will notice that using weight on information enables us to have an easy quantification of the information that flows in the production system. If a work order arrives in the system, the following interrogations are necessary to be taken in consideration while quantifying the value of information flow. What are the specificities or the properties of the materials that are to be processed? Who gave the production order or who ordained the starting of production? On what medium the production order has been received by operators (human or and machine)? Do the production steps arrived timely or do the operators are well trained to interpret technical data, drawing and design? Are they accessible and transparent? The above questions emanate from the characteristics of information flow presented in Table 2 (See "Appendix"). In this paper, the value of information flow is based on the type, dimension, the direction, the parameters, and the quality of information. To have all the responses to the above questions, an audit on shop floor is being carried out and the various weights are being defined for the case study.

Weight Model of Value of Information Flow for Audit Results Analysis

From the definition of the characteristics of information flow that constitute an information flow (IF), taking in consideration the weight attributed to the sub-characteristics of information flow in the audit that we carried out, we will define W as the weight attributed to each of the following sub-characteristics. Though this weighted model of

Fig. 1 ANN structure

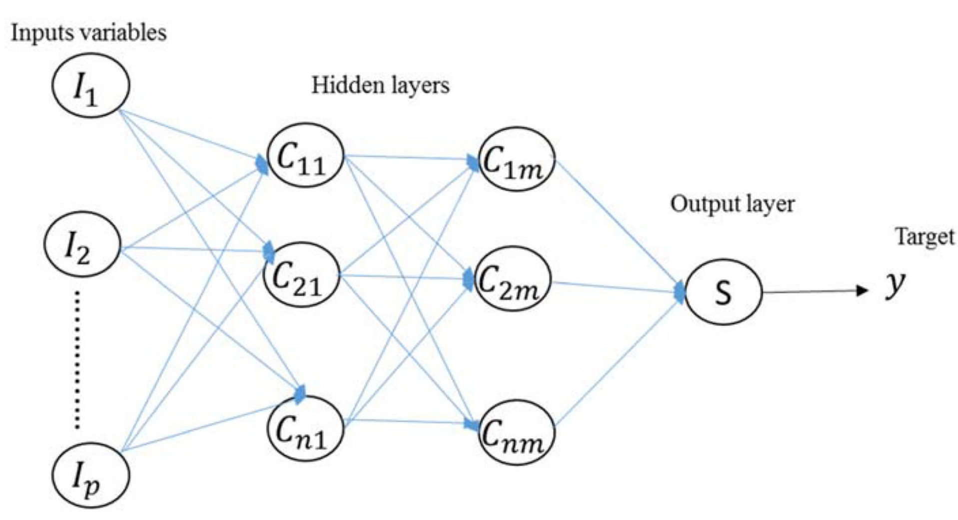

Table 1 Characteristics of the chosen ANN model

	Number of inputs	Number of hidden layers	Number of Output (VIF)	Number of nodes per hidden layers	Function of activation of hidden layers	Function of activation of output
First scenario	20	3	1	5	ReLU	Linear
Second scenario	16	3	1	4	ReLU	Linear

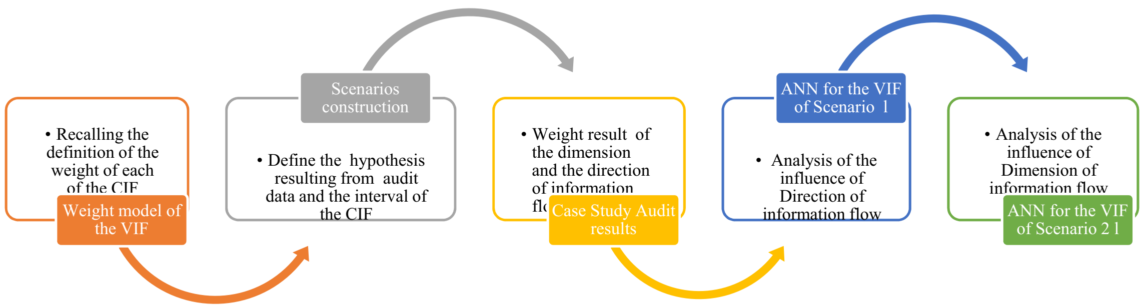

Fig. 2 Proposed methodology

the characteristics of information flow has been presented by Mbakop, Biyeme, et al. (2021), we reuse or recall it to evaluate the influence of direction and dimension of information flow on the performance of shop floor.

Type of information (TY) flow can be modeled as:

$$\mathrm{TY} = \frac{W(t_{ij})}{W_{TYT}} \begin{cases} W(t_{ij}) \text{ the weight of the type of information} \\ W_{TYT} \text{ the total weight of the type of information} \end{cases} \quad (1)$$

Dimension of information (DI) can be modeled as:

$$\mathrm{DI} = \frac{W(x_{ij})}{W_{DIm}} \times \begin{cases} W(x_{ij}) : \text{ the weight of the dimension of information} \\ W_{DIm} : \text{ the maximum weight of the dimension of information} \end{cases} \quad (2)$$

Direction of information (DrI) can be model as:

$$\mathrm{DrI} = \frac{W(y_{ij})}{W_{DRIm}} \times \begin{cases} W(y_{ij}) : \text{ the weight of the dimension of information} \\ W_{DrIm} : \text{ the maximum weight of the dimension of information} \end{cases} \quad (3)$$

The parameters of information (PrI) can be modeled flow as:

$$\mathrm{PrI} = \frac{\sum_{j=1}^{4} W(p_{ij})}{W_{PrIT}} \times \begin{cases} W(p_{ij}) : \text{ the weight of each component of the parameter of information} \\ W_{\mathrm{Pr}\,IT} : \text{ the total weight of the parameter of information flow} \end{cases} \quad (4)$$

Quality of information (QI) can be modeled as:

$$\mathrm{QI} = \frac{\sum_{j=1}^{4} W(q_{ij})}{W_{QIT}} \times \begin{cases} W(q_{ij}) : \text{ the weight of each component of the quality of information} \\ W_{QIT} : \text{ the total weight of the quality of information} \end{cases} \quad (5)$$

If N is the number of the characteristics (five in this case) of information flow containing the information flow, the VIF that we want to obtain for every information flow arriving in the system is described by Eq. (6).

$$VIF = \frac{\mathrm{TY} + \mathrm{DI} + \mathrm{DRI} + \mathrm{PrI} + \mathrm{QI}}{N} \quad (6)$$

The optimum value of information flow can be given by maximizing Eq. (7):

$$\begin{cases} \mathrm{TY} \leq 1 \\ \mathrm{DI} \leq 1 \\ \mathrm{DRI} \leq 1 \\ \mathrm{PrI} \leq 1 \\ \dfrac{\mathrm{TY} + \mathrm{DI} + \mathrm{DRI} + \mathrm{QI} + \mathrm{PrI}}{5} \leq 1 \end{cases} \quad (7)$$

It will be for a heavy task to examine the characteristics of information flow which maximize or minimize the value of information flow. For this reason, we will use the proposed ANN model proposed at Table 1 to achieve our results.

Construction of Scenarios

After analyzing the questionnaire given to company workers, it came out from their points of view that:

The type of information flow for the direct case can define the information concerning the raw materials of the product to be manufactured, the technical design description of the drawing, the quality material of the raw material to be processed, and for the indirect case. We can have the information resulting from the process related to the material, the machine, and the operator. From it, we have the following first hypothesis:

Hypothesis $\mathbf{H_1}$, the production processes of a raw material starts when the information about the raw material (direct information) is fully available to the operator (machine, human). The direct or the indirect information flow can take real value in the unit interval which is [0,1]. Thus, if the direct information value is 0, meaning the information concerning the raw material does not exist, the production process will not start. If the direct information takes the value 1, the production can start, for all the information concerning the raw material is available. Likewise, the indirect information can take a value if there is an information related to maintenance, order canceled by a customer, production errors, shortage of energy, availability of the operators (human or machine), if it has 0 as value it means that the indirect information does not exist.

Concerning the dimension of information flow in this case, we have considered the scale values of Tomanek and Schroder (2017).

Hypothesis $\mathbf{H_2}$, an information flow can only come from one direction and not more than two in order to avoid disruption and conflict. The direction of information can take values between the unit intervals.

An information flow can be sent from a higher position decision-making level (supervisor) to a lower position decision-making level (operator or machines), so the direction from which an information is received or sent can also be important and taken in consideration. An information coming from a manager to an operator may have a higher effect on the operator than an information coming from an operator to an operator.

Hypothesis $\mathbf{H_3}$, the information flow can only come from one direction not from more than two direction in order to avoid conflict in the decision making by operators. The direction of information flow can also take the real values in the unit interval.

The value of parameters obtained from information flow, which are velocity, viscosity, complexity, and volatility according to the level of influence of each of the characteristics, is defined in the unit interval.

Hypothesis $\mathbf{H_4}$, an information flow will have a poor value when it is volatile and viscous. The complexity of information depends on the capability of decoding of the person who receives the information.

Concerning the quality of information flow, all the sub-characteristics will have their value in the unit interval according to the answers received from audit. The transparency and granularity of information flow depend on the personnel appreciation, so it weighted value can vary from 0 to 1 but for machines it will remain binary value 1 or 0. The timeliness and the accessibility of information flow can also vary from 0 to 1. When the information is fully accessible and when it fully arrives and is timely, the value of these CIF is taken as 1.

Hypothesis $\mathbf{H_5}$, the value of information flow is null if an information flow is not accessible or/and not timely (value nearly equal to 1 for operators and 1 from machines) and also in this case, granularity and transparency values must be at least superior to 0.5. It has to be noted that the parameters of information flow have the same evolution as the quality of information flow.

It comes from hypothesis $\mathbf{H_1}$, $\mathbf{H_2}$, $\mathbf{H_3}$, $\mathbf{H_4}$, and $\mathbf{H_5}$ a first scenario of the analysis where there is the presence of parameters of information flow, which is the case of some shop floor poor industrial countries and also from $\mathbf{H_1}$, $\mathbf{H_2}$, $\mathbf{H_3}$, and $\mathbf{H_5}$ a second scenario of analysis where the problem of volatility, complexity, and viscosity of information have been solved. This hypothesis concerns the small companies in developing countries, namely Cameroon. The hypothesis construction diagram is shown by Fig. 3.

Results and Discussion

Audit Results

The audit results from small and medium size woodworking companies concerning the dimension of information flow show that 1% of the information flow shared within the operators of these companies is digital showing the way to digitalization of information for production operations is too far, 3% of information shared for production operations are electronic. These results also show that 10% applied the visual information, Kanban card and information pasted on board; 39% of information shared for production operations are on paper; 47% of information shared are being done by mouth to mouth, by phone or by alarm. The special case here of oral or audio information flow happens when there is a noise from a machine, then the operator is able to diagnose what happen on the

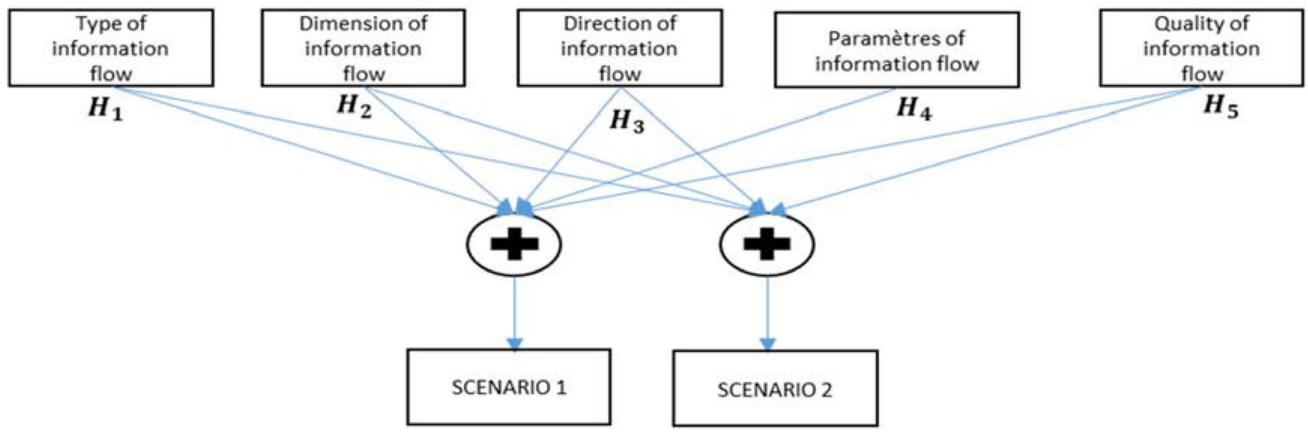

Fig. 3 Hypothesis construction diagram

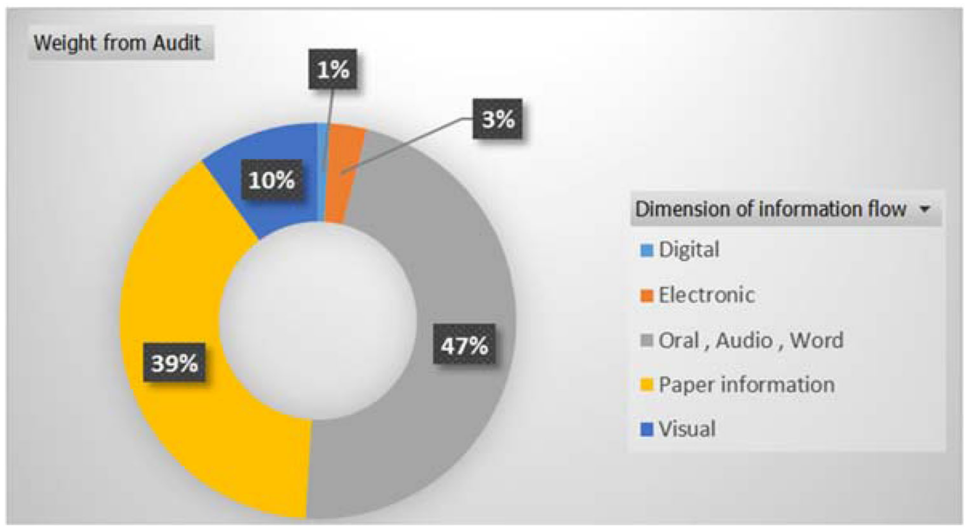

Fig. 4 Dimension of Information flow on shop floor woodworking companies

machine, or what is happening on the machine, be it for production or maintenance, Fig. 4.

The audit results from small and medium size woodworking companies concerning the direction of information flow show that diagonal information flow describing the information coming from expert represents 2% of the information flow shared in shop floor operations. The downward information describing the order to produce or to run the production from a supervisor or a maintenance instruction from a high level of decision making or from (from a machine B preceded by machine A) a low level represents 62%. The horizontal information flow describing the information shared between the same operators of the same level of production be it for human or for machines has a percentage of 29%. The upward information flow, moving from a low decision making to a high decision making (or from a machine B to a machine A), is not quite considered in such companies for it has the sharing percentage of 7%, Fig. 5.

Such company shop floor in production operations can model the shared information as presented by Fig. 6.

In this woodworking company, the information shared is function of the dimension and the direction flow in the shop floor; the behavior of operators (machine or human) depends on the medium and the level of decision-making hierarchy.

Integration of the VIF in the Woodworking Process

Technically, in a woodworking company where furniture is being fabricated daily, as it is the case of many shop floors, we proposed a flowchart for the interaction of information flow based on the CIF in woodworking processes as described by Fig. 7. This proposed model will transform the non-flexible shop floor to a flexible shop floor by increasing the performance of the shop floor. The description of the production process goes as follows:

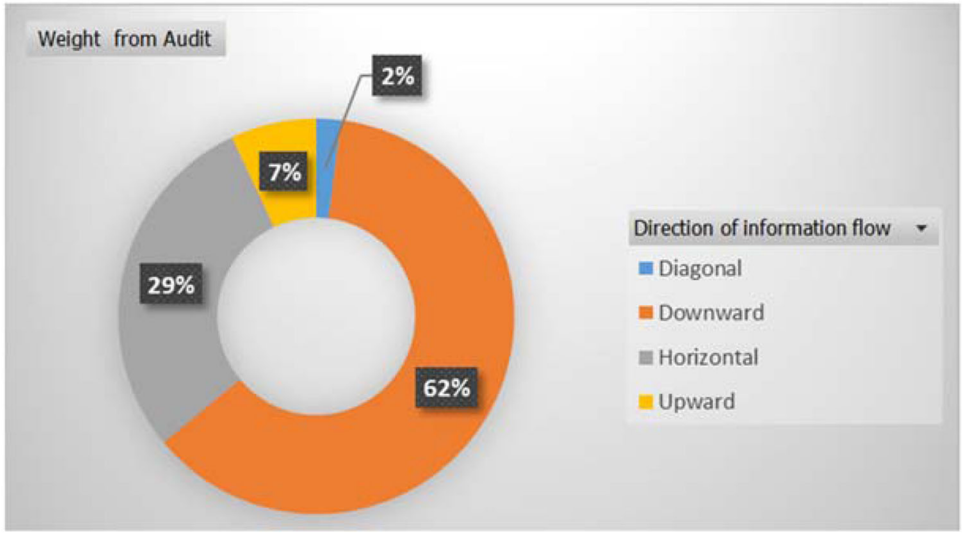

Fig. 5 Direction of Information flow in shop floor woodworking companies

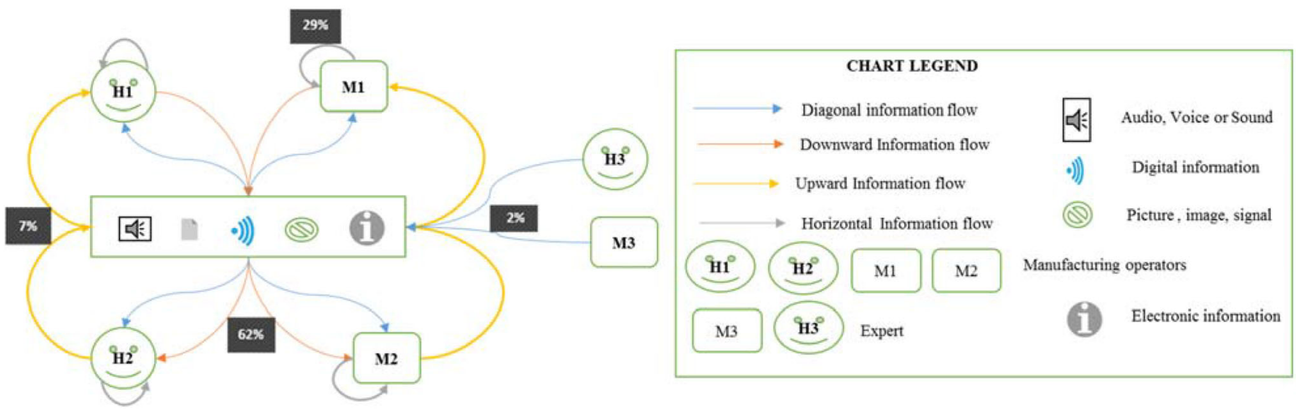

Fig. 6 Modeling Information flow sharing on the shop floor woodworking companies

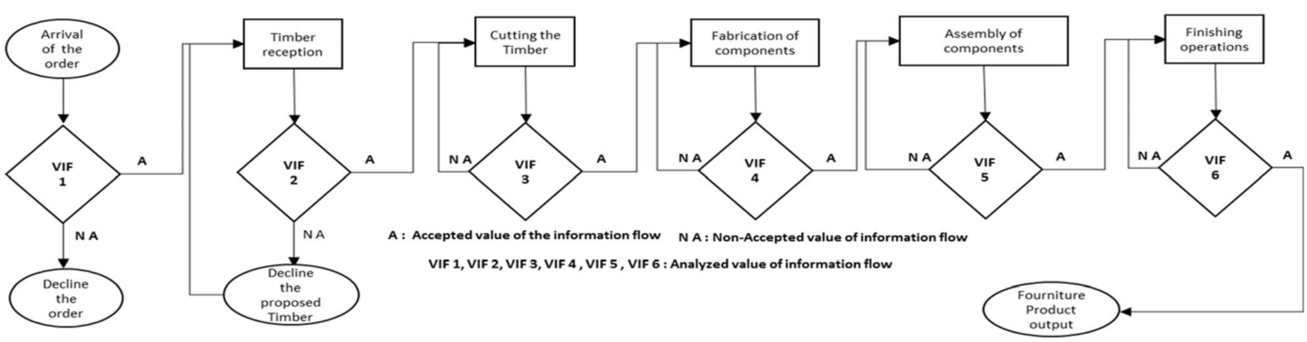

Fig. 7 A proposed flow chart for the interaction of information flow based on the VIF

When the order of a customer arrives on the shop floor, the production supervisor analyzes the VIF (VIF1) concerning the order. He will check if the shop floor has the necessary material, the operators, the machines, the established process, the technical drawing of the furniture proposed by the customer, after the checking if the VIF 1 has a poor value, the production supervisor will decline the order of the customer, if not he will ordain the arrival of the timber. The required information of the timber will be checked out (VIF 2). The VIF 2 will be to check who the supplier is or who delivered the type of the timber, what are the mechanical and chemical properties of the timber, and the verification of the related operations to be carried out on the timber. If VIF 2 is not accurate, then, another timber will be chosen but if it is acceptable. The operator will start the cutting operation of the timber. During the cutting operation, the VIF 3 signifies, the usage of the concerned machines (operators) by verifying their availability and the cutting tools condition with all the required parameters. The ability of the operator to interpret the technical code of the drawing and also the transparency and the details (granularity) of the cutting operations. If the result coming from VIF 3 is acceptable, then we move to the various fabrication of the components. This stage is also conditioned to the respect of the various specificities of the fabrications. These various specificities of the components are the size, the dimension, the machine setting up, the lubrication, the understanding, and the interpreting of the noise of machine (communication between the machine and the operator) when cutting, the interpretation of the nature of the chip. If VIF 4 is acceptable, we move to the next step which is the assembly operations, even this step is conditioned by VIF 5. After the assembly operations, the next step is the finishing process which is conditioned by VIF 6, if VIF 6 is acceptable then the production process will be stopped if not some checking actions has to be done.

After building the dataset from the audit results obtained, the ANN presented above was used to analyze the influence of dimension and direction of information (under the two scenarios mentioned) on the predicted VIF with a score of 0.99 for scenario 1 and 0.994 for scenario 2. The predicted VIF of the first and second scenario has been extracted and presented by Figs. 8 and 9. From the extracted sample of the predicted VIF inspired by the works of Mbakop, Biyeme, et al. (2021), we can therefore analyze the influence of the direction and the dimension of information flow on the VIF.

The Influence of Dimension of Information Flow on the VIF

Having a look on what Tomanek and Schroder (2017) did, the value of information flow on VAHM is essentially based on the dimension of information flow. The results obtained in the first scenario illustrate that the presence of the parameters of information flow such as volatility and viscosity can render null the value of an information flow; it is what Tomanek and Schroder (2017) called media disruptions which is the case of X^3 as presented in Fig. 10. From Figs. 10 and 11, the VIF for the digitalize (X^2) information is 0.9340 and 1.0131, respectively. It brings to understand that ANN can also be used to determine or predict the VIF both with parameters of information flow or not, depending on which form of company shop floor we find ourselves because according to the scale value of Tomanek et al. (2016), it is supposed to be 1 (or 5). The paper information flow (X^{20}) has as greatest VIF 0.8635 and 0.7205 according to the different scenario and when the quality of information is clearly met top as an accurate transparence, accessibility, timeliness, and granular, thus the value of information flow when having a paper

Characteristics of information flow of the first scenario																					**Output**
X	t_{11}	$,t_{12}$	x_{11}	x_{22}	x_{33}	x_{44}	x_{55}	x_{66}	y_{11}	y_{22}	y_{33}	y_{44}	p_{11}	p_{12}	p_{13}	p_{14}	Q_{11}	Q_{12}	Q_{13}	Q_{14}	**VIF_Pred**
X^0	1	0	0	0	0	0	0.8	0	0	0	0	0.9	1	0	0	0	1	1	1	0.7	0.84773
X^1	1	1	0	0.4	0	0	0	0	0	0.6	0	0	0.8	1	0	0	1	1	1	0	0.80106
X^2	1	0	0	0	0	0	0	1	0	0	0	0.3	1	0.1	0	0	0.7	1	1	0.1	0.9340
X^3	1	0	0	0	0	0.6	0	0	0	0	0	1	1	0	0.8	1	1	1	1	0	0.0017
X^4	1	0	0.2	0	0	0	0	0	0.9	0	0	0	1	0.1	0	0	1	1	1	0	0.7748
X^5	1	0	0.2	0	0	0	0	0	0	0	0	1	1	0.3	0.2	0.5	1	1	1	0	0.5618
X^6	1	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	1	1	0	0.93402
X^7	1	0	0	0	0	0.6	0	0	0	0	0.8	0	1	1	0	0	1	1	1	0.9	0.6823
X^8	1	0	0	0	0.4	0	0	0	1	0	0	0	1	1	0	0	1	0.4	1	0.8	0.0008
X^9	1	0	0	0	0.4	0	0	0	0	0	1	0	1	0.3	0	0	0.8	1	1	0.7	0.5208
X^{10}	1	1	0	0	0.4	0	0	0	0	0	0	0.7	1	0	0	0	1	1	1	0	0.5208
X^{11}	1	1	0	0.4	0	0	0	0	0	0.3	0	0	1	1	1	0	1	1	1	0	0.5208
X^{12}	1	0	0	0	0	0	0.8	0	0.8	0	0	0	1	1	1	0	1	1	0.2	0.9	0.5208
X^{13}	1	0	0	0	0	0	0	1	0	1	0	0	1	1	1	0.8	1	0.1	1	0	0.5208
X^{14}	0	1	0	0	0	0	0	1	0	0	0	1	1	0.2	1	0.2	1	1	1	0.9	0.5208
X^{15}	1	0	0	0	0	0.6	0	0	0	0.7	0	0	0.6	1	1	0.4	1	1	1	0.8	0.5208
X^{16}	0	0	0	0	0	0	0	1	0	1	0	0	1	1	1	1	1	1	1	1	0.5208
X^{17}	0	1	0.2	0	0	0	0	0	0	0	0.8	0	1	1	1	1	0.7	1	1	0	0.5208
X^{18}	1	0	0	0	0.4	0	0	0	0	1	0	0	1	0.5	1	1	1	0.9	1	0.5	0.5208
X^{19}	1	0	0	0	0	0	0.8	0	0.7	0	0	0	1	1	1	1	1	1	1	0.6	0.5208
X^{20}	1	1	0.2	0	0	0	0	0	1	0	0	0	1	1	1	0.6	1	1	1	0.6	0.8635

Fig. 8 Extracted values of the analysis of the VIF of the first scenario

	Characteristics of information flow of the second scenario																Output
X	t_{11}	t_{12}	x_{11}	x_{22}	x_{33}	x_{44}	x_{55}	x_{66}	y_{11}	y_{22}	y_{33}	y_{44}	Q_{11}	Q_{12}	Q_{13}	Q_{14}	VIF_pred
X^0	1	0	0	0	0	0	0.8	0	0	0	0	0.9	1	1	1	0.7	0.72095
X^1	1	1	0	0.4	0	0	0	0	0	0.6	0	0	1	1	1	0	0.80236
X^2	1	0	0	0	0	0	0	1	0	0	0	0.3	0.7	1	1	0.1	1.0131
X^3	1	0	0	0	0	0.6	0	0	0	0	0	1	1	1	1	0	0.7054
X^4	1	0	0.2	0	0	0	0	0	0.9	0	0	0	1	1	1	0	0.6475
X^5	1	0	0.2	0	0	0	0	0	0	0	0	1	1	1	1	0	0.6590
X^6	1	0	0	0	0	0	0	1	0	0	1	0	1	1	1	0	1.0070
X^7	1	0	0	0	0	0.6	0	0	0	0	0.8	0	1	1	1	0.9	0.6780
X^8	1	0	0	0	0.4	0	0	0	1	0	0	0	1	0.4	1	0.8	0.0007
X^9	1	0	0	0	0.4	0	0	0	0	0	1	0	0.8	1	1	0.7	0.6880
X^{10}	1	1	0	0	0.4	0	0	0	0	0	0	0.7	1	1	1	0	0.6880
X^{11}	1	1	0	0.4	0	0	0	0	0	0.3	0	0	1	1	1	0	0.6880
X^{12}	1	0	0	0	0	0	0.8	0	0.8	0	0	0	1	1	0.2	0.9	0.6880
X^{13}	1	0	0	0	0	0	0	1	0	1	0	0	1	0.1	1	0	0.6880
X^{14}	0	1	0	0	0	0	0	1	0	0	0	1	1	1	1	0.9	0.6880
X^{15}	1	0	0	0	0	0.6	0	0	0	0.7	0	0	1	1	1	0.8	0.6880
X^{16}	0	0	0	0	0	0	0	1	0	1	0	0	1	1	1	1	0.6880
X^{17}	0	1	0.2	0	0	0	0	0	0	0	0.8	0	0.7	1	1	0	0.6880
X^{18}	1	0	0	0	0.4	0	0	0	0	1	0	0	1	0.9	1	0.5	0.6880
X^{19}	1	0	0	0	0	0	0.8	0	0.7	0	0	0	1	1	1	0.6	0.6880
X^{20}	1	1	0.2	0	0	0	0	0	1	0	0	0	1	1	1	0.6	0.7205

Fig. 9 Extracted values of the analysis of the VIF of the second scenario

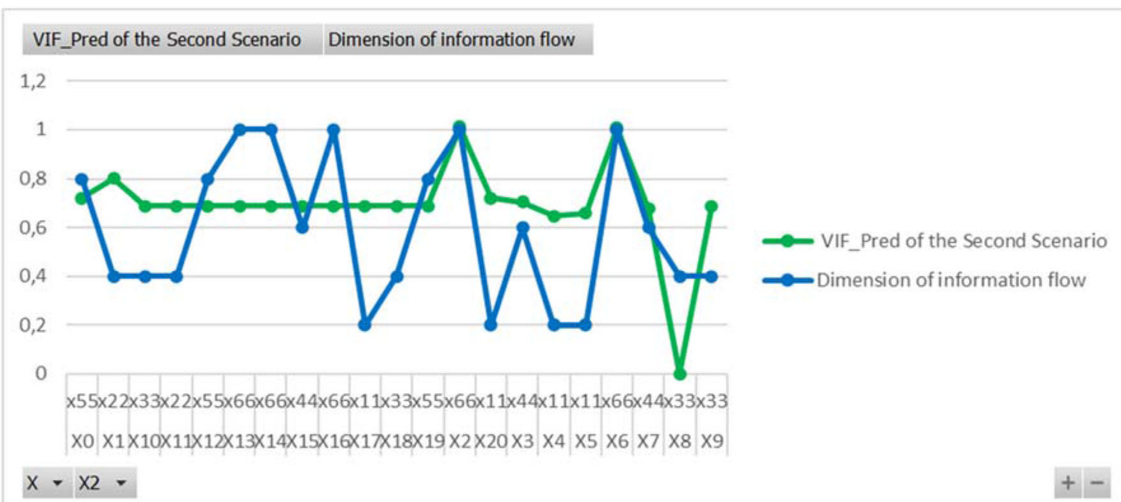

Fig. 10 Influence of the dimension of information on VIF of the second scenario

information for a production process cannot be null. The VIF obtained here is quickly above what Tomanek et al. (2016) found for they were at 1, whereas we are at 4. Therefore, when an operator is sharing all the information that required the product processing, it can then carry on the production; nevertheless, digital remains the best option. The visual information flow (X^{10}, Kanban board can also have a good value of information on the shop floor as presented in both scenarios) when all the maximization conditions are met up. In this sample, the highest value is 0.688 and it is almost equal to 3 but we can improve it when digitalizing the visual information on this shop floor. This is the reason for which Kanban board or ticket is mostly used in SMEs which are not high advanced in technology. The audio information flow mostly known as word information or sound and alarm in shop floor (X^4) has a VIF equal to 0.801 and 0.802 in the first and second scenario comparing it to the result obtained by Tomanek et al. (2016); it will be equal to 4 instead of 2. Thus, the value of information flow in a shop floor can not only depend on one or two characteristics, but also it is advisable to consider all the characteristics of information flow except those which can add a negative influence on the shared information such as parameters of information.

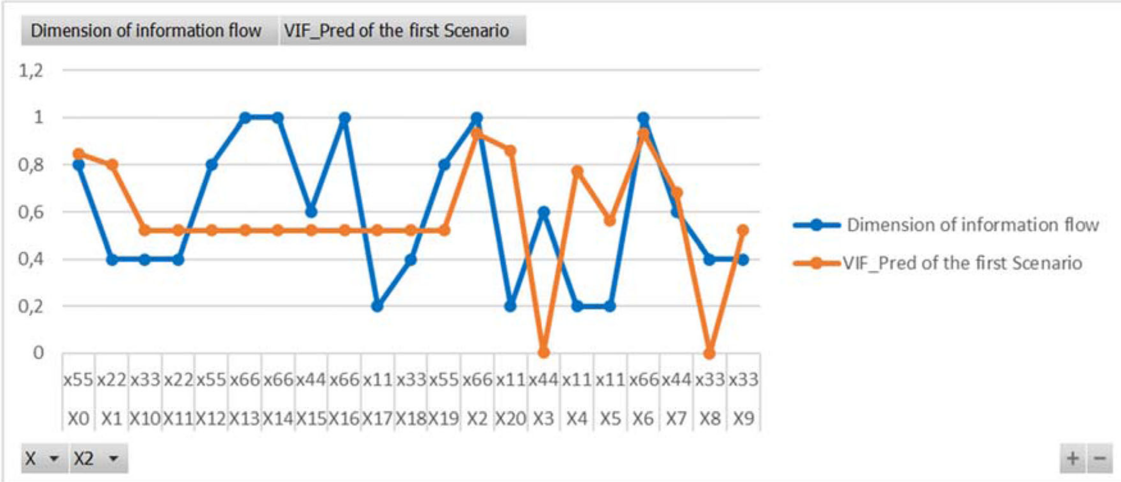

Fig. 11 Influence of the dimension of information on VIF of the first scenario

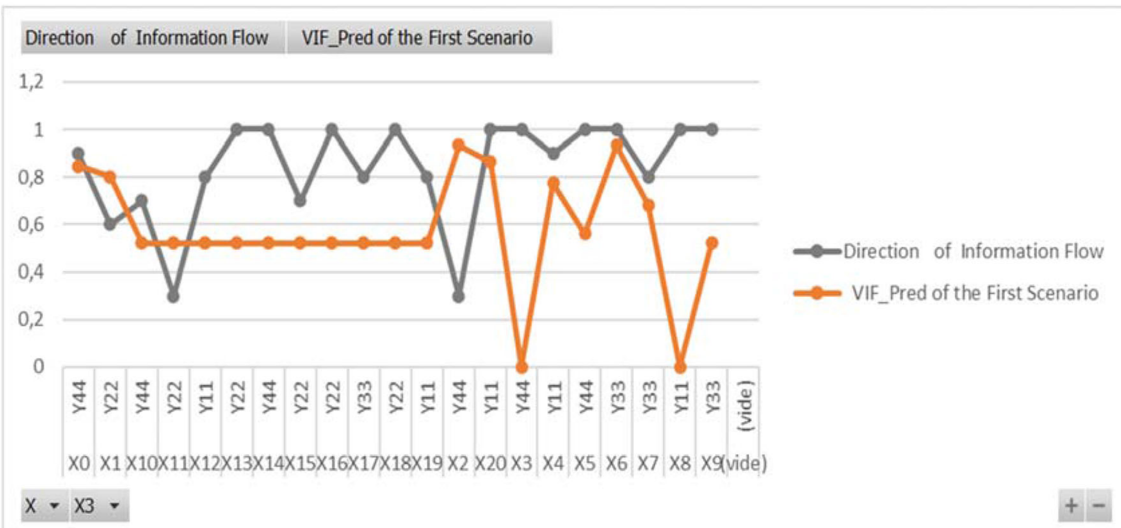

Fig. 12 The influence of the direction of information on VIF of the first scenario

The Influence of Direction of Information Flow on the VIF

From Figs. 12 and 13, the attention is paid where the value of the direction of information flow is almost equal to or matching with the VIF_Pred. It comes that from the first scenario, the information flow described by X^0 with Y_{44} (diagonal) as direction has 0.9 as value and 0.84773 as VIF_pred. For the second scenario, we have for X^{10} with Y_{44} (diagonal) having 0.7 as value and 0.688 as VIF_pred. From the above result, the dimension value of information and the VIF are similar under the influence of the presence of other positive characteristics. Practically, the diagonal information which can be taken as an external information coming from expert, consultancy, or certification recommendation for the production operations in the shop floor plays also a major role in increasing the VIF on the shop floor for production operation. Having a look at the horizontal information flow for the first and second scenario, the results obtained are as follows: 1 (y_{33},) and 0.934, 1 (y_{33},) and 1.007, for the information flow X^6, respectively. From the result obtained based on the horizontal information, we observe that the VIF_pred is also similar to it and that, the influence of the horizontal information toward the VIF_pred is also important under the conditions of having positive others characteristics.

On the shop floor, the horizontal information may always come from the colleague of the same level of decision making. It may come also from the machine from the same duty or operation tasks, and finally for human operators sharing the same production activities, the shared horizontal information in the shop floor is not to be

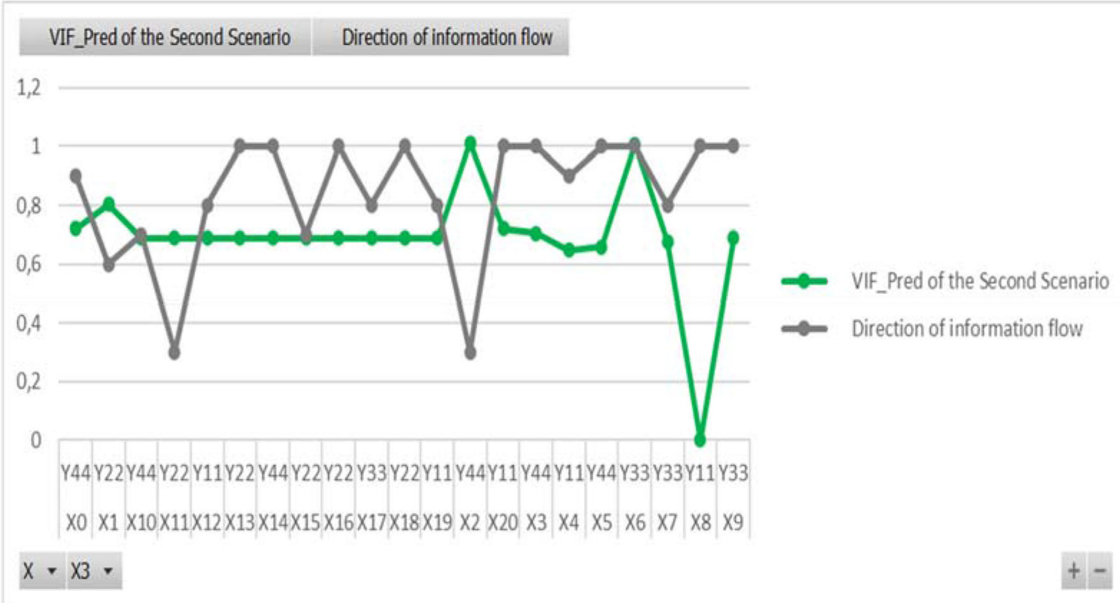

Fig. 13 The influence of the direction of information on VIF of the second scenario

minimize during the production operations under the conditions avoiding non-added VIF.

Future Research Directions

In some developing countries, there is still much to be done to improve the performance of the shop floor where production operations are being carried out. In this paper, we analyzed the impact that a decision level can have on a production operation task carry out by a human according to the information that is delivered to accomplish the duty and also according to the support that carried the information. This analysis had as objective, to render the shop floor flexible. Many managers can use this work to ameliorate their communication during production processes. And also taking in consideration the fact that though their company is not yet fully digitalized, they can still be efficient by computing the VIF at each step. After the computation of the VIF, they should improve the characteristics of information flow from job post to job post using the visual management technique and also having an ear opened to the constant information that is sent to them by machine operators. This paper will also improve the economic aspect of the company, because the development or the amelioration conditions of small- and medium-sized companies accelerate the economic growth according to Akinboade (2014), Puatwoe and Piabuo (2017).

However, the insufficiency of this work is that the performance obtained does not really tell us how to improve the production time and product quality. How can we determine the total production time of the production tasks on the shop floor based on the VIF to ameliorate the flexibility of the shop floor using the CIF? How can we use the VIF to proposed model of the quality inspection of production operations at each step using the CIF?

Conclusion

The continuous improvement of performance of small manufacturing companies in developing countries is not based only on timely delivery of quality product to customers but also on the management of information flow that contributes to the manufacturing processes of the product. The previous works on analysis of the management of information flow developed different methods to analyze and quantify the value of an information in a production line. The quantification analysis of the VIF was based just on one characteristic of information flow such as dimension; quality without using ANN. However, a deep analysis to determine the influence of direction and dimension of information flow on the VIF during shop floor operations was not tackled. This paper had as aim to analyze the influence of dimension and direction on shop the floor of developing countries taking as case study, Cameroon small and medium companies using ANN. The results of this paper link the flexibility with the dimension and the direction of information flow. Though we had major challenges in data collection and communication with companies, the results of this work show that, sometimes, the shared information from a high decision-making level to a low decision-making level (downward information) may have a high weighted (on the behavior of the operator) value even if the information wrongly influences the production process because of the supervisor's order. To avoid this, the production supervisor has to always give an open ear to machine operators because they are the one knowing the daily realities of the shop floor according to the specificities of the resources. Mouth-to-mouth information is used more in this type of shop floor and followed by paper information; digital information is left behind. In terms of VIF quantification, a shop floor can still be performant or flexible if using paper information and Kanban card on condition to paste the information on each board relative to job post, thus the visual management. The future research work that emerges from this paper is the determination of minimum production time of the job's tasks using the VIF to ameliorate the flexibility of the shop floor and also to propose a model of inspection of the quality inspection of the production operations at each step using the VIF.

Appendix

See Table 2.

Table 2 Description of the CIF in the production or manufacturing environment (Mbakop, Biyeme, et al. (2021))

Characteristics of information flow	Sub characteristics of information flow	Description in the production or manufacturing domain
Type of information	Direct information	Information related directly to the process, namely information about raw material, process transformation, customer order
	Indirect information	Information that may stop the production chain, information which influence indirectly the production. Machine breakdown or unavailable, personnel incompetent or absent or not well trained, void information discussed in the shop floor, machines settings, tools settings
Dimension of information	Documented or paper information	Manufacturing order, document of raw materials, remodification of product order, costumer order, work order, spare parts document, datasheet, history of breakdown document
	Audio, vocal information	Alarm for maintenance intervention, call, word to word information, recorded audio information
	Visual information	Images, pictogram, sign board, life information on the screen, Total productive management information on board, production key performance indicator on board
	Non-real-time electronic information	Information sent through email, fax, that necessitate a printer, logic automated with cable
	Real-time electronic information	Automated machine, sharing information through Grace sequences, or programming languages, or computer-aided manufacturing (CAM) and computer-aided design (CAD) sending information through cable
	Digital information	Interconnected things that share information, absence of electronic cable, information is shared wirelessly
Direction of information	Upward information	The information that is sent by a personnel (a machine, computer) of a lower decision level to a personnel (a machine, computer) of a higher decision level
	Downward information	The information that is sent by a personnel (a machine, computer) of a higher decision level to a personnel (a machine, computer) of a lower decision level
	Horizontal information	The information that is sent by a personnel (a machine, computer) of the same decision level to another personnel (a machine, computer) of the same decision level
	Diagonal information	The information that is sent between managers of different companies
Parameters of information	Velocity	The speed with an information is sent; it depends also from the support or medium of information. From an operation 1 to an operation 2
	Viscosity	The noise of the environment, the low connectivity, the incomplete information that can be find in an information for the execution of an operation
	Complexity	The understandability of the information, referring to the language with what information is flowing for a production operation to be executed
	Volatility	The loss of information when executing an operation or when moving from task 1 to task 2 in a manufacturing process, the loss of data
Quality of information	Transparency	The ease with which information that is passed from one task in a process to another can be understood
	Accessibility	The availability, the reliability, the ease to use of information on an operation or a task process
	Timeliness	Just in time information for the realization of a task process or operation
	Granularity	Information passed from one task 1 in a process to another task 2 has to be detailed

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References

Abdipoura, M., Younessi-Hmazekhanlub, M., Ramazanic, S. H. R., & Omidi, A. H. (2019). Artificial neural networks and multiple linear regression as potential methods for modeling seed yield of safflower (*Carthamus tinctorius* L.). *Industrial Crops & Products, 127*, 185–194.

Adam, M., Ibrahim, M., Ikramuddin, I., & Syahputra, H. (2020). The role of digital marketing platforms on supply chain management for customer satisfaction and loyalty in small and medium enterprises (SMEs) at Indonesia. *International Journal of Supply Chain Management, 9*(3), 1210–1220.

Agu, O. C., & Mbah, S. A. (2013). African firms manufacturing and economic development: Is Africa effectively competing in manufacturing in the world market. *IOSR Journal of Humanities and Social Science, 12*(3), 34–46.

Akinboade, O. A. (2014). Regulation, SMEs' growth and performance in Cameroon's central and littoral provinces' manufacturing and retail sectors. *African Development Review, 26*(4), 597–609. https://doi.org/10.1111/1467-8268.12116

Alam, N., & Al-Amri, H. A. (2020). Service quality perception and customer satisfaction in Islamic Banks of Oman. *The Journal of Asian Finance, Economics and Business, 7*(9), 499–504. https://doi.org/10.13106/JAFEB.2020.VOL7.NO9.499

Alcaide-Muñoz, C., Bello-Pintado, A., & Merino-Diaz de Cerio, J. (2018). Manufacturing strategy process: The role of shop-floor communication. *Management Decision, 56*(7), 1581–1597. https://doi.org/10.1108/MD-01-2017-0085

Aubert, B. A., Vandenbosch, B., & Mignerat, M. (2003). Towards the measurement of process integration. Scientific series of CIRANO (Centre Interuniversitaire de Recherche en Analyse des Organisations).

Bangre, A. (2018). Aligning skills in personnel with the lean system's requirements. Master's Thesis, University of Tennessee. https://trace.tennessee.edu/utk_gradthes/4976.

Bateman, N. A., Philp, L., & Warrender, H. (2009).Visual management and shopfloor teams—Utilising shopfloor knowledge. In EUROMA, Gothenburg. (industryforum.co.uk). Accessed on the 03 June 2021.

Berente, N., & Vandenbosch, B. (2004). Factors inhibiting information process integration, Case Western Reserve University, USA. Sprouts: Working Papers on Information Systems, 4(3). http://sprouts.aisnet.org/4-3.

Chi Anh, P., & Matsui, Y. (2011). Relationship between quality management information and operational performance. *Management Research Review, 34*(5), 519–540. https://doi.org/10.1108/01409171111128706

Çınar, Z. M., Abdussalam, N. A., Zeeshan, Q., Korhan, O., Asmael, M., & Safaei, B. (2020). Machine learning in predictive maintenance towards sustainable smart manufacturing in industry 4.0. *Sustainability, 12*, 8211. https://doi.org/10.3390/su12198211

Closs, D. J., Swink, M., & Nair, A. (2005). The role of information connectivity in making flexible logistics programs successful. *International Journal of Physical Distribution & Logistics Management, 35*(4), 258–277. https://doi.org/10.1108/09600030510599922

Contador, J. C., Satyro, W. C., Contador, J. L., & Spinola, M. M. (2020). Flexibility in the Brazilian industry 4.0: Challenges and opportunities. *Global Journal of Flexible Systems Management, 21*, 15–31. https://doi.org/10.1007/s40171-020-00240-y

Dey, S., Sharma, R. R. K., & Pandey, B. K. (2019). Relationship of manufacturing flexibility with organizational strategy. *Global Journal of Flexible Systems Management, 20*(3), 237–256. https://doi.org/10.1007/s40171-019-00212-x

Dawaikat, Y. N. (2017). Flexibility through information sharing evidences from the automotive industry in Sweden, Doctoral thesis KTH Royal Institute of Technology School of Industrial Engineering and Management Department of Industrial Economics and Management SE-10044 Stockholm, Sweden. FULLTEXT04.pdf (diva-portal.org). Accessed on August 11, 2021.

Evans, S., & Bahrami, H. (2020). Super-flexibility in practice: Insights from a crisis. *Global Journal of Flexible Systems Management, 21*(3), 207–214.

Göppert, A., Robert, L. M., & Schmitt, H. (2021). Predicting performance indicators with ANNs for AI-based online scheduling in dynamically interconnected assembly systems. *Production Engineering*. https://doi.org/10.1007/s11740-021-01057-z

Hosseinzadeh, A., Baziar, M., Alidadi, H., Zhou, J. L., Altaee, A., Najafpoor, A. A., & Jafarpour, S. (2020). Application of artificial neural network and multiple linear regression in modeling nutrient recovery in vermicompost under different condition. *Bioresource Technology, 303*, 122926.

Huo, B., Gu, M., & Prajogo, D. (2016). Flow management and its impacts on operational performance. *Production Planning & Control, 27*(15), 1233–1248. https://doi.org/10.1080/09537287.2016.1203468

Kaur, S. P., Kumar, J., & Kumar, R. (2017). The Relationship between flexibility of manufacturing system components, competitiveness of SMEs and business performance: A study of manufacturing SMEs in Northern India. *Global Journal of Flexible Systems Management, 18*(2), 123–137. https://doi.org/10.1007/s40171-016-0149-x

Lingitz, L., Gallina, V., Ansari, F., Gyulai, D., Pfeiffer, A., et al. (2018). Lead time prediction using machine learning algorithms: A case study by a semiconductor manufacturer. *Procedia CIRP, 72*, 1051–1056. https://doi.org/10.1016/j.procir.2018.03.148

Materna, L., Hinrichsen, S., Adrian, B., & Schulz, A. (2019). How to improve shop floor management. In *9th international conference production engineering and management*, Trieste, Italy, Conference paper.

Mbakop, A. M., Biyeme, F., Voufo, J., & Meva'a, J. R. L. (2021). Predictive analysis of the value of information flow on the shop floor of developing countries using artificial neural network based deep learning. *Heliyon*. https://doi.org/10.1016/j.heliyon.2021.e08315

Mbakop, A. M., Voufo, J., Biyeme, F., Ngozag, L. A., & Meva'a, L. (2021). Analysis of information flow characteristics in shop floor: State-of-the-art and future research directions for developing countries. *Global Journal of Flexible Systems Management, 22*(1), 43–53. https://doi.org/10.1007/s40171-020-00257-3

Meudt, T., Metternich, J., & Abele, E. (2017). Value stream mapping 4.0: Holistic examination of value stream and information logistics in production. *CIRP Annals, 66*(1), 413. https://doi.org/10.1016/j.cirp.2017.04.005

Mourtzis, D., Fotia, S., Boli, N., & Vlachou, E. (2019). Modelling and quantification of industry 4.0 manufacturing complexity based on information theory: A robotics case study. *International Journal of Production Research*. https://doi.org/10.1080/00207543.2019.1571686

Mourtzis, D., Fotia, S., & Vlachou, E. (2017). Quantification of industry 4.0 manufacturing complexity based on information theory. In *Proceedings of 7th IESM conference 2017*, Saarbrücken, Germany, October 11–13.

Muller, R. (2017). Impacts of implementing paperless practices at shop floor level on the information flow and the working processes Master of Science Thesis in the Supply Chain Management Programme. Chalmers University of Technology Gothenburg, Sweden 2018 Report No. E2017:137. Mall för omslag till examens- och kandidatarbete - med bild (chalmers.se). Accessed on the 03 June 2021.

Nakandala, D., Samaranayake, P., Lau, H., & Ramanathan, K. (2017). Modelling information flow and sharing matrix for fresh food supply chains. *Business Process Management Journal, 23*(1), 108–129. https://doi.org/10.1108/bpmj-09-2015-0130

Nowak, D., Marcinkowski, B., Narojczyk, S., & Zalizko, V. (2020). Modern methods used in production-operations management. Poznań University of Economics and Business. pp. 137–181. https://doi.org/10.18559/978-83-8211-059-3/05.

Ojstersek, R., Acko, B., & Buchmeister, B. (2020). Simulation study of a flexible manufacturing system regarding sustainability. *International Journal of Simulation Modelling, 19*(1), 65–76.

Palanisamy, R. (2012). Building information systems flexibility in SAP–LAP framework: A case study evidence from SME sector. *Global Journal of Flexible Systems Management, 13*(1), 57–74. https://doi.org/10.1007/s40171-012-0005-6

Puatwoe, J. T., & Piabuo, S. M. (2017). Financial sector development and economic growth: Evidence from Cameroon. *Financial Innovation*. https://doi.org/10.1186/s40854-017-0073-x

Richter, A., Vodanovich, S., Steinhüser, M., & Hannola, L. (2017). IT on the shop floor—challenges of the digitalization of manufacturing companies. In *Bled eConference*, Bled, Slovenia, 18 June 2017–21 June 2017. https://doi.org/10.18690/978-961-286-0431.34.

Shukla, S. K., Sushil, & Sharma, M. K. (2019). Managerial paradox toward flexibility: Emergent views using thematic analysis of literature. *Global Journal of Flexible Systems Management, 20*(4), 349–370.

Singh, R. K., Modgil, S., & Acharya, P. (2019). Assessment of supply chain flexibility using system dynamics modeling. *Global Journal of Flexible Systems Management, 20*(Suppl 1), S39–S63.

Suprapto, W., Tarigan, Z. J. H., & Basana, S. R. (2017). The influence of ERP system to the company performance seen through innovation process, information quality, and information sharing as the intervening variables. In *Proceedings of the 2017 international conference on education and multimedia technology—ICEMT '17*. https://doi.org/10.1145/3124116.3124131.

Tezel, A., Koskela, L., & Tzortzopoulos, P. (2009). The functions of visual management. In *International research symposium*, 2009, Salford, UK. This version is available at http://eprints.hud.ac.uk/id/eprint/29091/

Thomas, A. J., Petridis, M., Walters, S. D., Gheytassi, S. M., & Morgan, R. E. (2017). Two hidden layers are usually better than one. *Communications in Computer and Information Science*. https://doi.org/10.1007/978-3-319-65172-9_24

Tomanek D. P., Hufnagl, C., & Schrôder, J. (2020). Determining the digitalization degree of information flow in the context of industry 4.0 using the value added heat map. In A. Kolinski, D. Dujak, & P. Golinska-Dawson (Eds.), *Integration of information flow for greening supply chain management. EcoProduction (Environmental Issues in Logistics and Manufacturing)*. Springer. https://doi.org/10.1007/978-3-030-24355-5_10.

Tomanek, D. P., & Schroder, J. (2017). Analyzing the value of information flow by using the value added heat map. In D. Dujak (Hrsg) *Proceedings of the 17th international scientific conference business logistics in modern management*. Faculty of Economics in Osijek, 86.

Tomanek, D. P., Schröder, J. & Wirz, M. (2016). Value added heat map—a new method for the optimization of production space. In T. Sawicz (Ed.), *13th international conference on industrial logistics (ICIL 2016)*, Alnus Sp. z o.o, Krakow, 315–323.

Torres, D., Pimentel, C., & Duarte, S. (2020). Shop floor management system in the context of smart manufacturing: A case study. *International Journal of Lean Six Sigma, 11*(5), 823–848. https://doi.org/10.1108/IJLSS-12-2017-0151

Tran, V. D., & Le, N. M. T. (2020). Impact of service quality and perceived value on customer satisfaction and behavioral intentions: Evidence from convenience stores in Vietnam. *The Journal of Asian Finance, Economics and Business, 7*(9), 517–526. https://doi.org/10.13106/JAFEB.2020.VOL7.NO9.517

UNIDO. (2021). Challenges to Industry 4.0 | UNIDO Knowledge Hub, accessed the 17/03/2021 AT 12: 08 am.

Vilarinho, S., Lopes, I., & Sousa, S. (2018). Developing dashboards for SMEs to improve performance of productive equipment and processes. *Journal of Industrial Information Integration*. https://doi.org/10.1016/j.jii.2018.02.003

Wadhwa, S., Madaan, J., & Verma, M. (2009). Flexibility focused decision and information sharing model for product recovery system. *Global Journal of Flexible Systems Management, 10*(3), 15–22. https://doi.org/10.1007/bf03396563

Wei Ng, Y., Ren Jie, J. C., & Kamaruddin, S. (2014). Analysis of shop floor performance through discrete event simulation: A case study. *Journal of Industrial Engineering, 2014*, 10, Article ID 878906. https://doi.org/10.1155/2014/878906.

Key Questions

1. How can we determine the total production time of the production on the shop floor based on the VIF to ameliorate the flexibility of the shop floor?
2. How can we use the VIF to propose a model of the quality inspection at each step of the production line or chain?
3. How can we set up in place a dynamic system to control the VIF in real-time in the production line in order to improve it flexibility?

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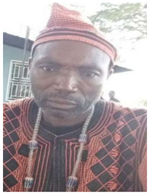

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