



Analysis of Information Flow Characteristics in Shop Floor: State-of-the-Art and Future Research Directions for Developing Countries

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Abstract *The information flow in a company is a whole set of static or dynamic data obtained from communication used for the conception and realization of products; facing competition, every company aims at improving its performance to meet customer needs. The focus on information flow to improve the performances of companies has always been a major preoccupation in the research domain, which always contributes to the evolution of the analysis of information flow for companies to be more efficient. This article presents the state of the art on the analysis of information flow model based on information characteristics in shop floor manufacturing companies (known as advanced in technology) to ameliorate their performance and future research directions for small- and medium-sized*

manufacturing companies for developing countries to be more competitive and efficient.

Keywords Information characteristics · Information flow · Manufacturing companies · Performance · Shop floor

Introduction

The ever-increasing economic challenge in an industrial environment has become highly competitive due to the demands of customers in terms of meeting deadlines. The quality of the product delivered has pushed manufacturing companies in a perpetual dynamics in order to improve their services, while minimizing the cost factor linked to the services rendered for continuous improvement in the production flow management. Poor management of production flows has always caused poor performance of the company (Durugbo et al. 2011; Durugbo and Erkoyuncu 2014). Production flow management calls two types of flows, physical flows (materials, work in process) and information flows (all information involved in the production process). Management of flows in manufacturing company can be done by the management of information flow (MIF). According to Tomanek et al. (2020), there is profitable for production companies to move from a paper information to digitalization. The digitalization of information sharing (information technology) has been of a great help in the MIF of manufacturing companies (Richter et al. 2017). We can illustrate this information flow sharing based on information technology between the actors (human and machine) in the shop floor as shown in Fig. 4 (“Appendix” section).

Although the information technology is at the center of every manufacturing growth in advanced technology, in some developing countries, the management of information

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flow has not yet met up with the high standard of the industry 4.0 because of the lack of transfer of technology and the economic situation of companies (Agu and Mbah 2013; Saymeh and Sabha 2014). Focusing our attention on small- and medium-sized manufacturing companies (SMMC), information flow is often shared (the medium) vocally, with papers, even with gesture (in a noisy environment), and with Internet depending on how each company manages its information flow in various manufacturing departments. Information flow can also be shared from human to machine and from machine to human, the medium of information sharing influences the quality of information that one receives. A common view on how information flow is shared in shop floor of developing countries is based on machinery, joinery, metalworking and welding processes as shown in Fig. 5 (“Appendix” section). From Fig. 5, there is a gap of management of information flow because the digitalization has not been implemented in some developing countries. For this reason, the information flow in motion inside the manufacturing units has to be of a great interest in order to ameliorate the performance of these SMMC, knowing that wrong information or defective information can occur waste in the company (Schroder and Tomanek 2012).

For SMMC of developing countries to be more efficient and be at the high standard of manufacturing technology, their information system management has to be updated by having a look at the analysis of the information flow approach, knowing that the analysis of information flow is based on: Which information is delivered, when will information be delivered, how will information be delivered, where will information be delivered, to whom will information be delivered. Assuming that every information can be characterized, how did SMMC analyze the information flow based on its characteristics to improve their performance? What were the limits of their research? What are the future research directions for developing countries based on the previous limits to improve the performance of their SMMC in order to be more competitive? These are the questions that this work will tackle based on the analysis modeling of the information flow. To carry along our work objectives, a general knowledge of information flow presentation will be done, followed by the research work on the analysis of information flow and ending up with a discussion that will lead to future research directions.

General Knowledge on Information Flow

Definitions of Information Flow

The information flow can have several definitions depending on the context in which it is used. It is the sum

of the verbal, written, recorded and computer data, it can be visual or not, but most of the time, it is visual (Thomas 1993; Müller et al. 2017). Depending on the application domain, information flow can be considered as a set of data semantics (Lee 1999), it can also be a part of the different types of flow that requires synergy between modern organizations and computer systems (Mentzas et al. 2001), and according to Lueg (2001), information flow can also be viewed as a signal. In modern organizations, information flow is also considered to be a vital element of a process as well as product development in companies (Eppinger 2001). The information flow can also be defined as an interaction between humans and computer systems (Hinton 2002). Standing on the look of its importance, information flow is as oxygen is for men (Al-Hakim 2008). The information flow can also be taken as data and documents to describe the communication between production and the control of production process, between the actors and the services of a company (Erlach 2010; Koch 2011; Durugbo et al. 2013; Razzak et al. 2018). Information flow can be considered as the communication that is shared between a working team (Stapel and Schneider 2012). Finally, according to Sundram et al. (2020), information as communication is part of information technology.

The different definitions of information flow lead us to have a look at the characteristics of information flow.

Characteristics of Information Flow

The characterization of the information flow can be done by its dimension referring to the medium of information sharing, by its parameters which present the dynamic of information flow, by its direction which defines the level of circulation of the information flow (class of information), by its type which presents the direct impact of information flow on the product or the customer and also by its quality.

Dimension of Information Flow

The dimension of the information flow can be considered as having access to information, exchange information and making information to be visible (Demiris et al. 2008). The dimension of information flow in the literature is presented as the medium through which information is shared. There can be several mediums that can be used to share information such as written information (documented information), electronic information in non-real, electronic information in real time and digital information referring to Internet of things (Tomanek and Schroder 2017). The information flow can't only be characterized by the dimension but by dynamics parameters also.

Parameters of Information Flow

When an information is in motion, it can be characterized by four parameters: Information node density, which describes the complexity of the information flow, the second parameter is the information velocity which denotes the speed of information, the third parameter is the information viscosity which is the level of information conflict at a node, it can also be known as the presence of contradictory information and the fourth parameter is the information volatility, which describes the uncertainty of the information (on paper) or the delay information, (Krovi et al. 2003). The information flow can also be characterized by identifying the different directions that it can take in the company called the classes of information according to certain authors.

Direction of Information Flow

The information flow can also be characterized according to the direction where it is transferred; we can distinguish the downward information, which is described as an information that is shared from members of top management and their collaborators. For the upward information, employees exchange information with their top management; for the horizontal information sharing, information circulates between the actors present in departments of the same category. Finally, the direction of information flow can also be qualified as diagonal when there is cross-functional communication between managers of different companies (Forza and Salvador 2001; Global Assignment 2019). To characterize the information flow, we can also consider the type of information which is shared.

Types of Information Flow

Based on the company's activities, the information flow can be of two types, the first one (direct information) is composed of every information that is needed to produce a product in the production process (information related to manufacturing or maintenance) or a service, whereas the second one (indirect information) is formed of all information related to future markets and customers (Chibba and Rundquist 2004; Samiei and Habibi 2020).

Quality of Information Flow

The quality of information flow has a large impact on its reception and its interpretation that is why poor quality information flow can be detrimental to the company (Kehoe et al. 1992). The information flow can have these qualities: transparency, granularity and timeliness; transparency describes the capability of workers to understand

the information delivered to them, granularity refers to the level of detail of the information and timeliness describes the availability of information when required (Durugbo et al. 2010; Tomanek and Schroder 2017). The fourth quality of information flow is the cost of information flow which refers to the cost that an information can input or output while manufacturing a product, researcher has been only focused on the cost of information related to the product to be delivered to customers (Ballou et al. 1998; Hanafizadeh and Nik 2020). The characterization of the information flow is resumed in Fig. 1.

Proper Illustration of Allocated Characteristics of Information Flow in a Shop Floor

Most often on shop floor, work order launches the beginning of shop floor operations or activities, according to Chibba and Rundquist (2009), in an industrial company, information can be shared between workers on paper (documented writings), on oral communication and also through computer. Let us consider here our information flow as the work order (WO) arriving in the shop floor. Assuming that we want to undergo series of operations in the shop floor to manufacture a product, Fig. 2 presents the characteristics of the arrival of a WO in the shop floor.

After the presentation of the characterization of the information flow, we will be focused on the research work that has been done so far to improve performance of manufacturing companies based on the analysis of the characteristics of the information flow on shop floor.

Analysis Models of Information Flow Based on Information Characteristics in Shop Floor

From the characteristics of information flow, some information analysis models in shop floor have been carried on by certain researchers to improve the performance and the efficiency of manufacturing in shop floor.

Ballou et al. (1998) presented a model that can be used to characterize the information product to be delivered to the customer, based on the determination of the deadline, quality, cost and value of product information for manufactured product to be delivered to customers. They used the matrix analysis method to bring out an information model deadline and cost from the manufacturing process. Just having a look at certain characteristics (as the deadline and cost) of product information without considering the direction of information is not enough to ameliorate the performance of a company, that is why Forza and Salvador (2001) analyzed an information flow model for the performance of a company based on the cost, the time and the quality in three operational processes and three directions



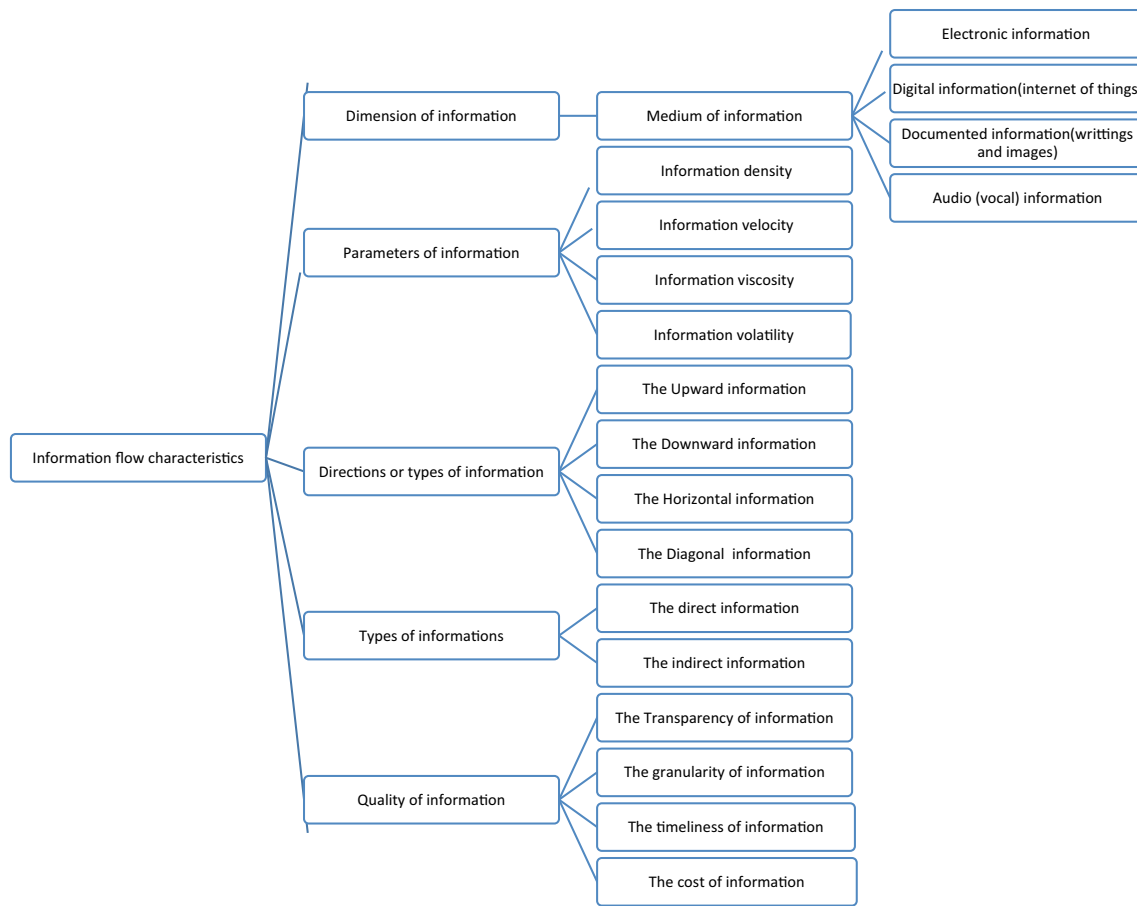


Fig. 1 General characterization of information flow

of information flow (vertical, horizontal and external information flows), they have not integrated the influence of the dimension (medium) of information on company performance. After considering the approaches of the dimension analysis of information flow, Sun and Jiang (2007) analyzed the information flow by considering the concept of manufacturing information, they proposed a manufacturing sharing and controlling method in which they established a mathematical (made of vectors) model of information sharing among the workers. Information flow can ameliorate the performance of a manufacturing process in a company by also considering the analysis of the sharing of information between departments, that is why Htay et al. (2013) identified the information related to the different operating departments (stamping shop, welding shop, painting shop) of production used in welding to manufacture cars, they considered the circulation of information quality between these departments to improve the quality of the product resulting from welding. At the end of their work, they brought out a three model information flow, one presenting the specific information flow in a welding workshop, the second presenting the process of internal inspections and the third presenting the process

of external inspections. However, they have not considered that information can not only circulate between the operating levels of the company but also between all the elements or actors (machines) involved in the manufacturing of a product, this is why Jabur and Dawood (2015) brought out an analytical model of the information flow between all the actors of communication (man and man, man and machine, machine and machine, man and computer, machine and computer, and the computer and the computer) entering in the manufacturing and assembly process of a product with the matrix method for controlling the information flow facilitating the planning and scheduling of tasks; from this work, it shows that the information flow existing between man and man is the most recurrent in the execution of tasks in a workshop of job shop type; in their work, they did not take into account the influence of the transmission medium of the information flow in the manufacturing process and assembly. Based on a certain manual assembly for trucks and engine, Johansson et al. (2017) focused their work on the analysis of data and information handling in manufacturing systems on shop floor operation. Their analysis aims to identify what information flow is made available for operators and also

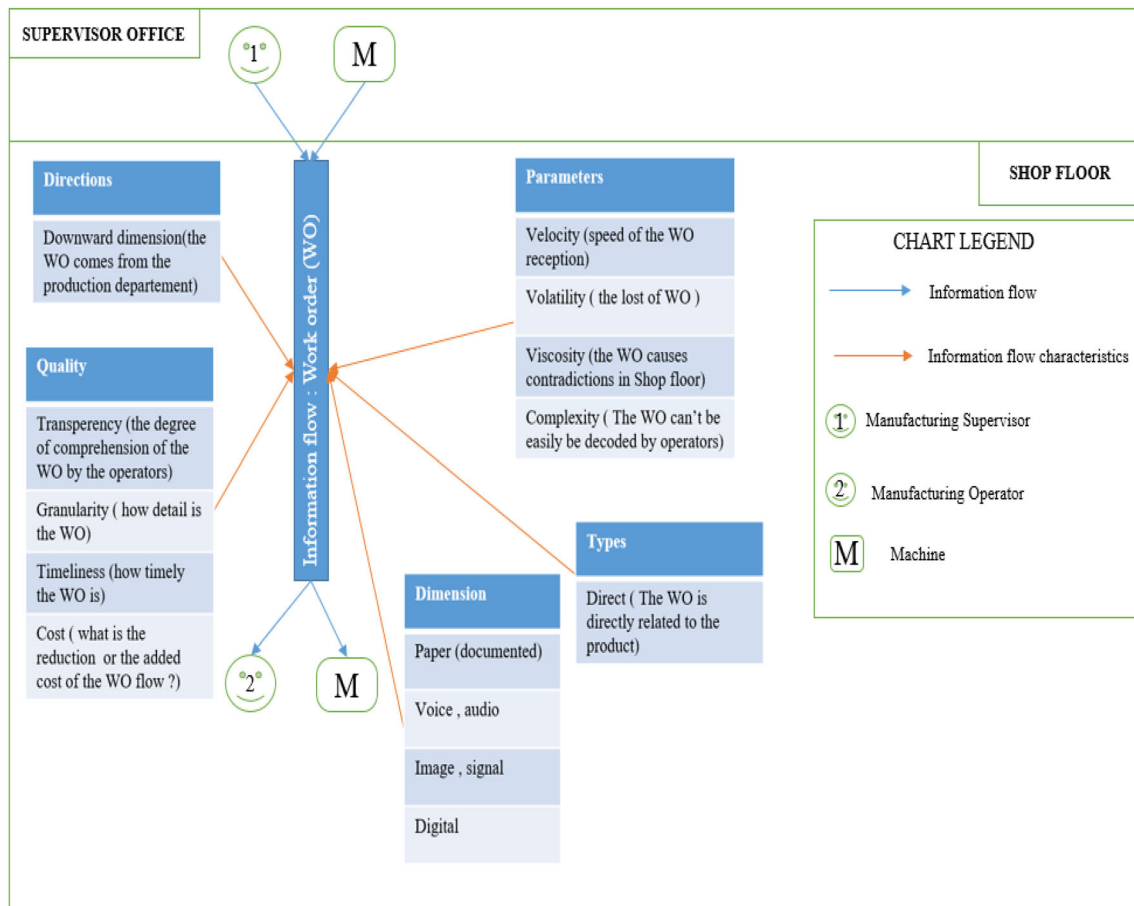


Fig. 2 Characterization of the arrival of a work order in a shop floor

the importance of this information flow to the operators as assembly work in a shop floor. From their results, three medium of information assembly to be shared to the operators in the assembly cycle are as follow: printed paper information, digital information and pick-2-light and at the end of their work, they remarked that the none consideration of information by certain operators has negative effects of the product assembly quality. Remaining on the same characteristics which are the medium or the dimension of information flow, Tomanek and Schroder (2017) analyzed the added value of the dimension (medium) of the information flow by the Value Added Heat Map method on production located in a manufacturing plant, they distinguished the different channels of information (emails, paper media and voice information), which they assigned added values emerging from production according to the degree of errors arising from the transmission of messages. It emerges from their work that the medium of communication Internet of things (IoT) has a great added value on production. Information quality which is also a heavy characteristic of information flow to influence the manufacturing performance in the shop floor has pushed Sütöová

and Segiňáková (2018) to identify the possibilities for improving the processing data and information (the timeliness and quality) received from customers in relation to the quality of the product in the process of automobile construction, which leads to better decision-making on the quality of the product produced and also allowing a reduction of imperfections, costs related to manufacturing and also the operation time needed by the operator to manufacture a product. They brought out an information model to communicate with customers throughout the product manufacturing process, the imperfections related to the product which are noticed by the customer are therefore adjusted by the competent operators to improve the quality of the product manufactured, which will consequently improve their manufacturing time.

After the presentation of the integration of the characteristics of information in the modeling of information flow, we present a summary of the articles identified according to their work focus as follows.



Summary of Articles Identified for the Analysis Models of Information Flow Based on its Characteristics in Shop Floor

The summary of the articles identified according to their focus on the characteristics of information flow in the analysis information models in the shop floor is presented in Table 1.

The illustration of the block diagram summarizing the essential point of articles in Table 1 is presented in Fig. 3.

Discussion

The characteristics of information flow in which researchers looked upon to analyze the information flow model and their impact on performance in manufacturing shop floor are presented in Table 1.

From their work, the following observations emerge:

- The quality of information which integrates timeliness, cost, transparency and granularity has been of a great focus in the analysis of the information flow model due to the impact of what a timely transparency information can have on shop floor tasks. Some researchers were interested in the dimension of information that enables the information to be transferred on time, to be accessible and to be well interpreted. According to Bäckstrand (2010), the information medium or dimension may activate the attention of operators on shop floor and lastly a few just directed their concerns on the direction of information which tells us how the shared information moves between manufacturing departments.
- The parameters and the types (of information) as characteristics of information flow in the shop floor were not considered according to the articles that we have consulted in the analysis models of information flow in shop floor, whereas information parameters are

well to describe an information flow in motion to the different workstation.

- Combination of quality with dimension and also of quality with the direction to improve the performance in shop floor for manufacturing company was considered because it takes a proper medium (dimension) to deliver timely information (quality) for operators in shop floor to execute their tasks to meet up with product key performance and good information can also come from a manager or people with whom they interact in the shop floor.

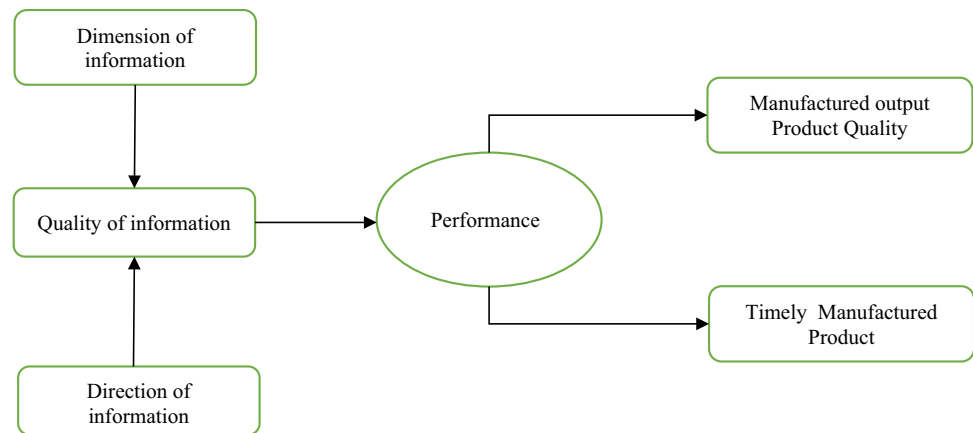
From the table presented, though the information quality is the pillar among all the information characteristics, it has to be combined with other characteristics such as the dimension or the direction to facilitate the flow of information in the shop floor activities, in order to see their impact on manufacturing time and product quality.

- The performance of a shop floor in terms of delivering a timely quality product is subjected to the combination of the following characteristics of information flow: the dimension, the direction and the quality according to Fig. 3.
- A consideration of more than two characteristics related to information quality of information flow for shop floor performance according to what we read has not yet been a point of focus. It will be of major curiosity to have a look at the quality of information flow associated with at least three other characteristics (dimension, the direction, parameters, the type) to model the influence of these information flow characteristics in manufacturing time and quality product in shop floor. It shall be a heavy advantage for the amelioration of the performance of SMMC for developing countries which are still in the door of the increasing technology and for countries which have not yet totally migrate to smart manufacturing.

Table 1 Recapitulation of the analysis of information flow model in shop floor based on information characteristics

Authors	Dimension	Direction	Quality
Ballou et al. (1998)			✓
Forza and Salvador (2001)		✓	✓
Sun and Jiang (2007)	✓		
Htay et al. (2013)		✓	✓
Jabur and Dawood (2015)	✓		
Tomanek and Schroder (2017)	✓		✓
Johansson et al. (2017)	✓		✓
Sütöová and Segiňáková (2018)			✓

Fig. 3 Information flow analysis diagram for the amelioration of shop floor performance



- In manufacturing, shop floor information may also occur sometimes randomly, when the work (planning or scheduling) in the shop floor is disorganized, a stochastic information (when information is needed by operators) can affect the delivery time of a product and also the quality of the product, this case has not yet been considered according to the articles that we read.
- Many articles had a look at the cost of information to be delivered to the customers and the cost of information related to the production process and the assembly one, but these have not brought out a clear model presenting the manufacturing cost due to the influence the information to be shared among operators while integrating at least three of these information characteristics.
- Human resources managerial output in the articles that we consulted has not been a point of focus based on the influence of information flow characteristics, whereas according to Oluwatayo and Adetoro (2020), human resource management can influence the job engagement of employees and consequently the performance of the company.
- Flexible manufacturing in shop floor based on information flow characteristics has not been considered as a research focus, whereas flexible manufacturing company or organization can be continuously efficient when predictable and unpredictable events related to consumers, markets, machines, and environment occur (Sushil 2017; Dey et al. 2019; Shukla et al. 2019; Singh et al. 2019; Contador et al. 2020; Evans and Bahrami 2020; Ojstersek et al. 2020).

Future Research Directions

Many works have been done on the analysis of information flow based on the characteristics of the information to improve the performance of manufacturing companies of high information technology. Because these works exist already, to avoid doing the same work or in order to bring out originality in future works concerning our research topic we will be focused on the particularity of SMMC in developing countries that are still struggling to embrace high manufacturing technology and which are still in traditional manufacturing. The future work directions that can be developed by solving the problem of performance arising from this state of the art in shop floor of SMMC are as follows:

- Analysis model of the influence of at least three characteristics of the information flow in shop floor based on manufacturing time and quality output product.
- Analysis model of the influence of at least three characteristics of the stochastic information flow in shop floor based on manufacturing time and quality output product.
- Comparative study of the analysis model of the influence of the stochastic (and none) characteristics of the information flow on manufacturing time and quality output product.
- Modeling of manufacturing cost due to the shared information among operators in shop floor of small and medium companies.
- Analysis of the information flow characteristics on operator's shop floor management.
- Contribution to flexible manufacturing modeling in shop floor based on the characteristics of the information flow.

Conclusion

Information flow has always been a vector, which ameliorates the performance in manufacturing companies in general and in SMMC in particular. Our article aimed to bring out a state of the art on the analysis of information flow model based on information characteristics in shop floor of SMMC in order to give out future research directions for developing countries to improve the performance of their SMMC. It emerges from this state of art that researchers mostly focused on the quality of information flow combined with the dimension and the direction of information flow to improve the shop floor performance. But they did not have a look at the impact of combining more information characteristics with quality to regard the output performance. Future opening research directions emerge from this work as follows: The analysis model of the influence of at least three characteristics of the information flow on shop floor performance in terms of time and quality output product, the analysis model of the influence of least three characteristics of the stochastic information flow on shop floor performance time and quality output

product. A comparative study on the analysis models of the influence of least three characteristics of the information flow (stochastic and none stochastic) in terms of time and quality output product, modeling of manufacturing cost due to the shared information among operators. The analysis of the managerial impact of these information flow characteristics of shop floor operators and finally a contribution to flexible manufacturing modeling in shop floor influenced by the characteristics of the information flow.

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Compliance with Ethical Standards

Conflict of interest The authors hereby declare that there are no potential conflicts of interest in terms of authorship, research and/or publication of this article.

Appendix

See Figs. 4 and 5.

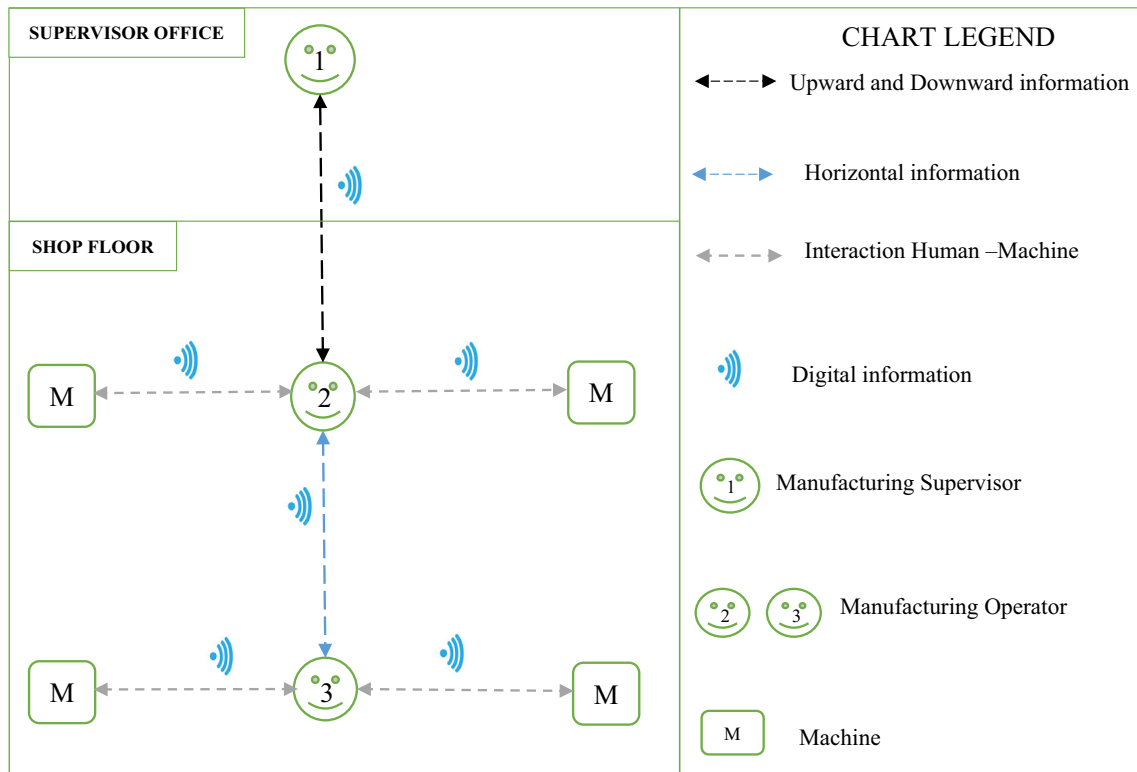


Fig. 4 Information flow sharing in firms of advanced technology countries



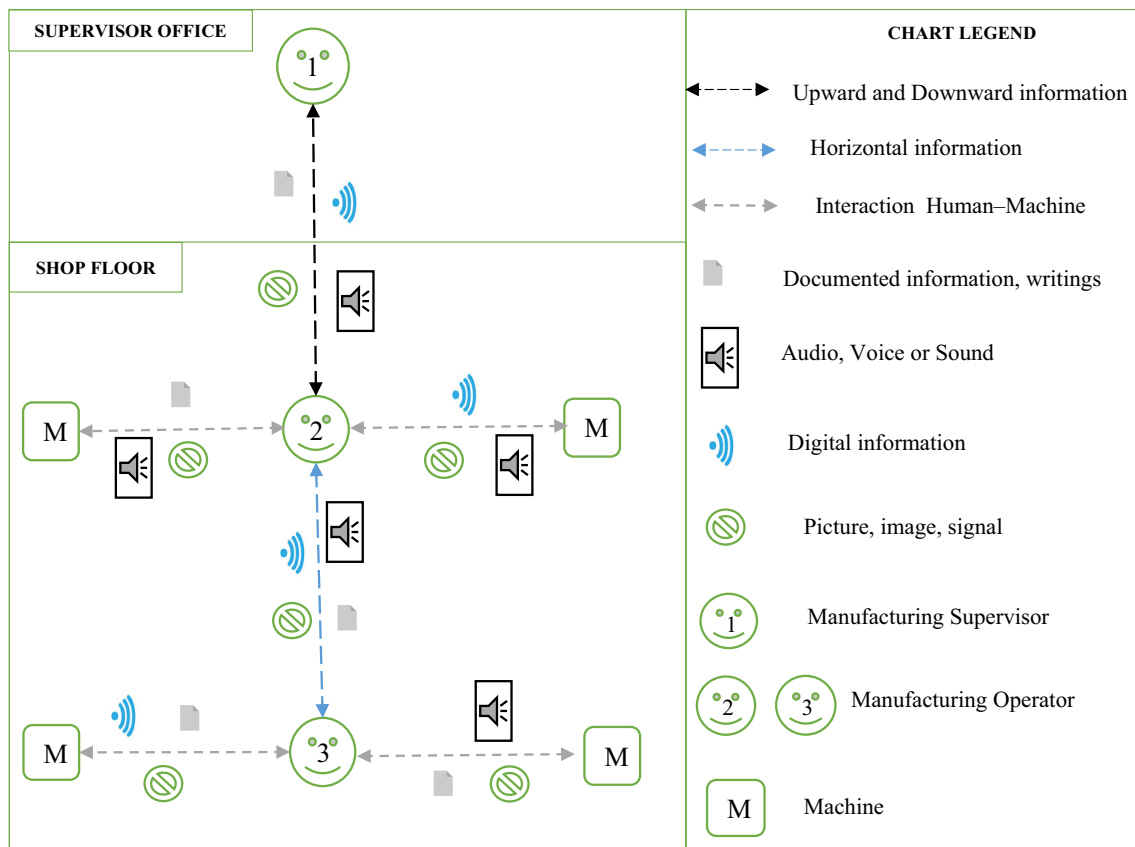


Fig. 5 Information flow sharing in small- and medium-sized manufacturing companies of developing countries

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Key Questions

1. How would the characteristics of information flow influence the performance of a flexible manufacturing system in shop floor?
2. What is the impact of stochastic information flow on shop floor performance based on the operator's management and tasks scheduling?
3. How can we evaluate the cost of the information flow characteristics on a manufactured product?



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