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ORIGINAL CONTRIBUTION

An Empirical Study on Information Flow Analysis Through Supply Chain Value Stream Mapping in an Automotive Industry

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Abstract Effective information flow is a key parameter for enhancing the performance of the supply chain. Information sharing provides a vital method for the endurance of enablers and enterprises to integrate the supply chain. This study explores the effectiveness of the supply chain information sharing practice of Indian automotive industries through the identification of the most important information sharing type, thereby improving the information sharing practice level. In this study, information about the demand planning is identified as the most important information and is frequently shared among the supply chain of Indian automotive industries manufacturing the interior parts of global passenger car. Current state value stream mapping was developed to analyze the demand information flow in the supply chain. This empirical study reveals that there is scope for improvement in information sharing practice by reducing the lead time of forward and reverse information flow between the supply chains.

Keywords Supply chain · Information flow · Demand planning · Value stream mapping · Automotive Industry

Introduction

Information sharing in supply chains has taken a center stage in the discourse of business and research in the last few decades because the information is not only the linchpin for companies for leaping ahead but also the key to survival [1]. However, like the wastes that are present in a production environment, there seem to be wastes present in the information sharing process also and this part of the work attempts to identify such wastes and apply the lean principles and the technique of value stream mapping to effect improvements in the performance of the concerned organization.

The lean management fundamentally aims to minimize wastes incurred in overproduction, inventory, special processing, transportation, waiting or queuing, excess motion, defect or rework, and utilized people [2]. The cardinal objective is achieved by using the five lean principles, namely value specification, value stream identification and waste elimination, value, flow mapping without interruptions, value pulling by customers, and perfection pursuit. The value of manufacturers is measured by delivering the right product to the correct place at the right time for the right price in the right quantity [2]. This study aims to raise the competitiveness of the Indian automotive industries by eliminating wastages and reducing the non-value added activities by the application of lean concepts and the VSM technique with a specific focus on the information sharing process.

Table 1 describes the significance of various abbreviations and their meanings used throughout this article.

Value Stream Mapping

Value stream mapping (VSM) was originated by Mike Rother and John Shook in collaboration with James Womack and intended to capture process information, materials flow, and information flow for a given product family. Although value stream maps were developed within the context of the automotive industry, they have become popular

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Table 1 List of abbreviations

Abbreviation	Meaning
VSM	Value stream mapping
OEM	Original equipment manufacturer
PP	Production demand plans
IS	Inventory status
OS	Order status
P&S	Purchase and sales information
QS	Quality status
DS	Delivery schedule
PD	Product development status
DSp	Design specifications
PPC	Production process cost
MMT	Material management team
FI	Forwrad information
RI	Return information
LT	Lead time
PT-FI	Process time for forwarding information
PT-RI	Processing time for return information
WT-FI	Waiting time for forwarding information
WT-RI	Waiting time for return information
LT-FI	Lead time of forwarding information
LT-RI	Lead time of return information
TLT	Total lead time
CFT	Cross-functional team
Engg	Engineering

in other fields such as health care and the service sector [1, 3]. VSM is a visualized technique for mapping current and future flows of materials and information across the supply chain from end-to-end activities. The activities are classified into three categories, namely non-value added, value added but necessary, and wastes. The last one is identified and eliminated aiming to bridge the gap between the current-state map and the envisaged future-state map. In general, a timeline is also plotted along the bottom of the value stream to track metrics used for cumulative quantities such as total lead time, total travel distance, and total value added time. These cumulative quantities help to characterize the value stream and serve as a baseline for later comparison [4]. Once the current state value stream map has been drawn, improvement opportunities can now be identified in a visual manner in conjunction with an assessment of the metrics. With respect to improving the current state value stream, Rother and Shook [3] take the view that the main objective in a lean enterprise is simply for any process to only make what the next downstream process requires, within the shortest lead-time, at the highest quality, and at the lowest cost. Belokar et al. [5] addressed the application of VSM as one of the Lean tools to eliminate waste and improve operational procedures and productivity, and the study revealed that there is an improvement in the takt time by implementing the proposed changes if incorporated in the future-state map. Jeyaraj et al. [6] identified the excessive takt time, production and lead time by comparing the current and future state of a manufacturing firm by utilizing VSM technique for production improvement.

Sheth et al. [7] utilized the VSM technique to identify and eliminate different types of wastes in the fastener industry and thus process inventory, production lead time, processing time, and distance traveled by material are reduced, which lead to reduced overall costs in the supply chain. Andrade et al. [8] identified and eliminated the waste and reduction of lead time in an assembly line of clutch discs. From the literature review, it is found that very minimum studies conducted by using VSM in the field of supply chain management and the present work, probably the first of its kind of work, focuses on information flow analysis through value stream mapping, in an automotive industry.

Research Background

Production and manufacturing wastages are generally understood and easily visible. According to TaiichiOhno, there are seven types of waste available in the manufacturing environment such as overproduction, inventory, transportation, motion, waiting, extra processing, and defects [9] (Schniederjans et al., 2009). On the other hand, in the area of information sharing and management, waste identification is tough to understand. Only very few previous researchers [1, 3, 6, 10] have analyzed the service, information sharing, and lean management issues and they define the wastages in the section of lean information sharing. For example, McManus and Millard [11] directly reinterpreted Toyota's seven wastes (excess information, transfer of information, waiting for information, preprocessing/lack of information, storing of information, searching of information, and wrong information) into manufacturing information sharing. Based on these observations, an attempt is made to identify the types of waste in the information-sharing process [6, 7, 11–17].

Methodology

The purpose of this case study is to attempt to reduce the information sharing processing time in a supply chain with a specific focus on an Indian automotive supply chain through the application of the concepts of VSM. The proposed approach is concerned with the identification of wastages and non-value added activities in the information-sharing process of an organization through the VSM technique.

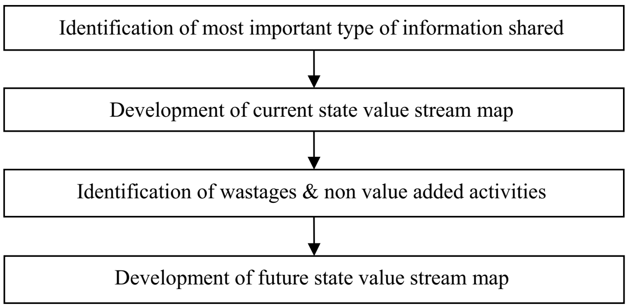

Fig. 1 Proposed methodology

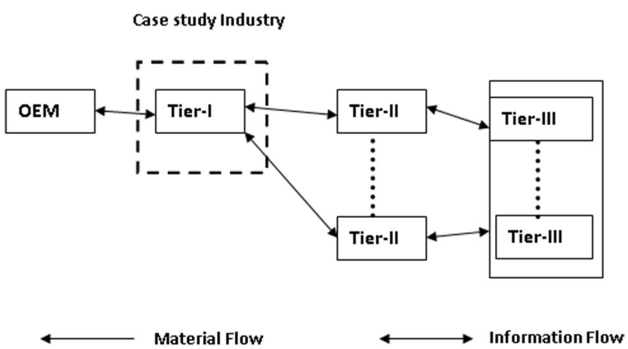

Fig. 2 Supply chain structure showing the material flow and information flow

Figure 1 presents the details of the steps involved in the proposed approach.

Case Study

About the Focal Organization

The focal organization considered for the present study is one of the leading Tier I automotive industries in South India, consists of four main stages, namely assembling plants, auto-parts manufacturing plants at Tiers I and II, and other supporting (i.e., machine, mold, steel, plastic parts, foam) industries, represented as Tier III industries. The assembling plants are owned by overseas companies (e.g., Hyundai, Toyota, Honda, Ford, Nissan, BMW, etc.), whereas Tier I and Tier II industries are owned by either multinational or Indian companies.

In the past years, the case company has experienced more complications in supply chain coordination with high work-in-progress inventory and difficulty in capacity and resource planning due to fluctuations in demand. Figure 2 shows the flow of information and material among the supply chain members of the case study industry. As shown in Fig. 2, the material flows from the upstream to downstream and thus between the Tier III, Tier II, Tier I organizations, and original equipment manufacturer (OEM), and the flow of information travels in both directions upstream and downstream. The case study industry belonging to the Tier I category receive the information from OEM and transfer it to Tier II. Then, Tier II industries transfer the information to Tier III industries. On the other hand, the return information is transferred from Tier III to Tier II, and from Tier II to the case study industries (Tier I), and finally, the case study industry communicates to OEM.

Challenges Faced by the Case Study Industry

The situation can be represented by the following issues.

1. Frequent changes in demand plan and consequential rush orders in the supply chain complicate supply chain coordination.
2. Focus on high resource utilization in each plant and less or no coordination in batch sizes between plants, resulting in large batch sizes and subsequent higher inventories.
3. Traditional information exchange, with limited information transparency (only Tier I plant can see customer, namely the OEM's, demand) and lack of collaborative planning processes.
4. Forward and reverse information sharing are not complete.
5. Many details or information are hidden from Tier II vendors.
6. Absence of and also unsupportive, delayed reply from Tier II vendors, as often the case industry does face the problem of noncompliance from Tier II vendors concerning sending replies for the information sought by the case industry.
7. Communication format and approval process vary among the supply chain members and within the case industry team members.

The study of the current scenario reveals that, despite inventory sharing practices among the members of the supply chain in place, there exist certain deficiencies as mentioned above; it is also noted that unnecessary or waste information is present in the information sharing process that hampers the efficiency of the supply chain. It is thought that application of the lean thinking and the technique of value stream mapping can help in improving the performance of the supply chain and the work carried out in this direction is described in the following sections.

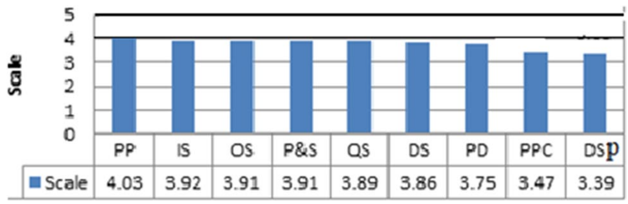

Fig. 3 Types of information shared by the members of the supply chain

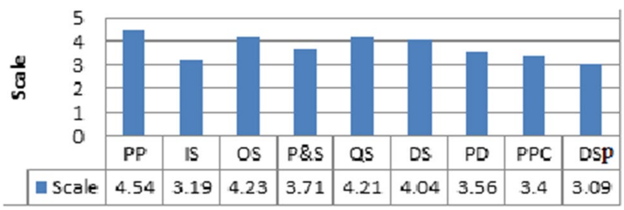

Fig. 4 Frequency of types of information shared

Identification of the Most Important Information Shared

Different types of information are shared between the members of the automotive supply chain depending on their needs and the data collected in this regard from the members revealed that the most widely shared types of information, in the specified order, are production demand plans (PP) followed by inventory status (IS), order status (OS), purchase and sales information (P&S), quality status (QS), and delivery schedule (DS) of the part,s and these pieces of information are communicated between the customer and suppliers. On the other hand, information related to new product development status (PD), production process cost (PPC), and design specifications (DSp) of parts get communicated between the chain members. The graphical representation of the data extracted from the survey among the members is shown in Fig. 3.

The survey results about the frequency of information sharing**,** the extract of which is presented in Fig. 4, reveal that the most frequently shared information is related to PP followed by information on IS, OS, P&S, QS, DS, PD, PPC, and DSp. Based on these observations, it is concluded that the PP is the most frequently as well as widely communicated type of information from OEM to Tier III industries and the study focuses on this information.

Development and Analysis of the Current State Map

The current value stream of the case industry is mapped as shown in Fig. 5. This process is started with the identification of the various departments to be considered in the study, which is then followed by the identification of activities involved in the process of information sharing along with the estimation of process times for these various activities or processes that are concerned with information flow in both forward and reverse directions. In the present study, the case study organization is a Tier I industry in an automobile supply chain, and the customer upstream is the OEM of the automobile manufacturer and the vendors are the downstream subpart manufacturers at the Tier II level. The production planning and control department coordinates the planning and execution of activities, and after receipt of the information on the demand plan from the OEM, the PPC department communicates this information to the production department, engineering department, and material management team (MMT) for checking the feasibility of the plan and also to ensure smooth operation. On getting the feasibility status report, which involves the flow of information in the reverse direction, the feasibility status is communicated back to the OEM.

From the Fig. 5, it is observed that the information flow takes place in both forward (downstream flow) and return (upstream flow) direction, and accordingly, the time consumed by the various activities are identified below. Process time for forwarding information (PT-FI), the processing time for return information (PT-RI), waiting time for forwarding information (WT-FI), waiting time for return information (WT-RI), lead time (that comprises of process time and waiting time) of forwarding information (LT-FI), lead time of return information (LT-RI), and the total lead time (TLT), which is the total time for the completion of information-sharing process in both forward and return directions. A close study is made to split the activities involved, and the timings for these activities are noted and presented in Table 2.

The time duration for the various activities are categorized into PT-FI, PT-RI, WT-FI, WT-RI, LT-FI, and LT-RI departments wise, and the summation of these time durations in respect of each department is presented in Table 2 and the graphical representation of this data is shown in Fig. 6. The summary of the various components of time for the information sharing process is depicted in Table 3, which reveals that the total time consumed in the information sharing process is 122.1 h at present. It is also estimated that the demand increase at present is 12,318 units.

From Table 3, it is found that the total lead time to complete the information process is 122.1 h, with the time for forwarding information flow as 39.1 h and return information flow as 83 h. From Table 2, it is revealed that, among the various processes under consideration, the MMT, vendor, and stores consume a large amount of processing time. Also, the MMT and vendor do spend a lot of time waiting for the information. The demand quantity is observed to increase at each stage of the process, namely PPC, MMC,

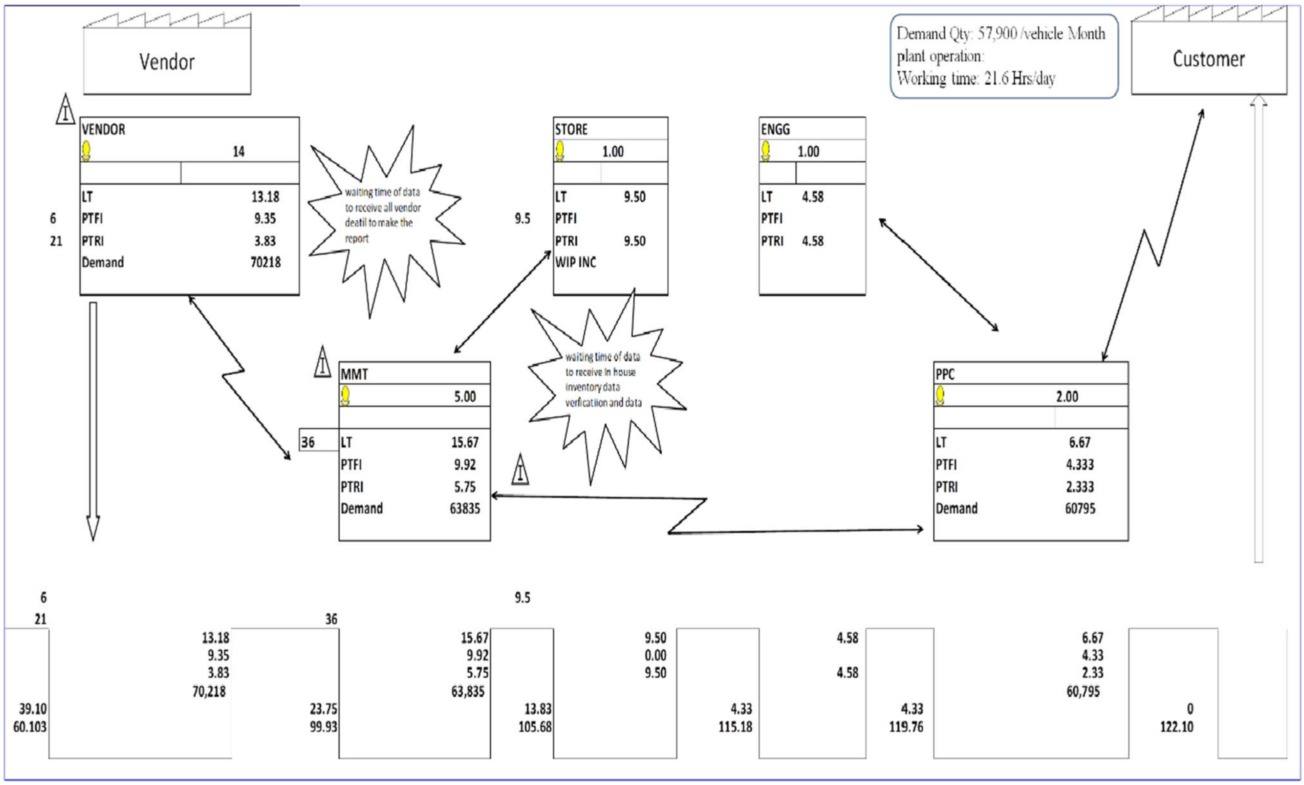

Fig. 5 Current state map

Table 2 Lead time for information sharing (Current state)

Process department	Activity time in hrs			
	Forward information sharing (FI)	Return information sharing (RI)	Waiting time	LT
PPC	4.333	2.333		6.67
Engg		4.58		4.58
MMT	9.92	5.75	45.50	61.17
Store		9.50		9.50
Vendor	9.35	3.83	27.00	40.18
Total	23.60	26.00	72.50	122.10

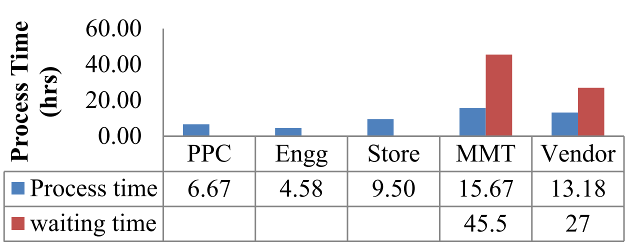

Fig. 6 Lead time for information sharing (Current state)

Table 3 Details of information sharing process times (Current state)

Process detail	Process time (hrs)
WT-FI	15.5
WT-RI	57.0
PT-FI	23.6
PT-RI	26.0
Process time (Total)	49.6
LT-FI	39.1
LT-RI	83.0
TLT	122.1
Demand increase (car set)	12,318

and vendor, and the total difference in demand increase is found to be 12,318 sets as against the demand of 57,900 sets from the customer end.

Based on the analysis, it is suggested that the case industry may focus on the following strategic actions to improve the efficiency of the process.

1. Creation of a cross-functional team (CFT) comprising two persons from each process and representatives of vendors.
2. Providing appropriate training to the CFT on the information sharing process, lean thinking, and VSM technique.
3. Analysis of the current state process and identification of the seven information wastages and non-value added activities.
4. Preparation of the improvement schedule.
5. Standardization of the common communication format.
6. Conduct weekly meetings by the CFT, to communicate the related issues for each process and stock status.

From the current-state map of the case industry, it is found that there is a scope for improvement in two potential areas, namely MMT and vendors' information systems. Further, it is found that the MMT and vendor do spend more time waiting for information due to different communication formats and data segregation. The waiting time for material management is observed to be 45.5 h and for the vendor process, it is 27 h.

Development and Analysis of Future State Map

From the current state mapping, it is found that the case company is facing the issue of incomplete information due to a lack of reply for the forward information or due to the reason that some of the vendors do not reply in time or take a long time to reply, and this is found to result in high information-processing time (122 h). The outcome of the current state mapping is taken up for analysis with the knowledge of management and the CFT is constituted with the concurrence of the management to improve the information process. The CFT meetings are conducted regularly every weekend to analyze the key issues to effect improvements and a target schedule of 2 months was framed for improvements.

The study on the present scenario shows the presence of many non-value activities both for the forward and return flow of information and, in consultation with the persons concerned, these non-value activities are eliminated. It is noted that the most observed non-value activity is due to data segregation in all functional departments under consideration, and this is due to the reason that each of these departments uses different models and formats for this purpose. Following the concepts of 5S, a standard data collection format is developed for this purpose that makes data segregation easier and faster and stores the data in a common server with identification which saves time.

As regards the MMT is concerned, it is observed that the information received and forwarded to the team members by the team leader results in more time or even, sometimes, missing communication from the team leader with consequential time delays. To reduce this time delay, it is proposed to adopt group communication wherein all the active members will receive the necessary information. It is also observed that the MMT receives the status of inventory every month and sometimes this becomes irregular and there seem to be inaccuracies in inventory-related data. To improve the accuracy of inventory-related data, it is proposed to input the data on production and inventory on a shift-wise basis on a common server, which is also expected to improve accessibility. Arrangements are also made to enable the stores to input the data on material availability on a common server so that the MMT receives the real-time stock status for material planning and material order to the vendor. It is also suggested that the organization may conduct monthly inventory verification so as effect close monitoring of the inventory status. The vendors are also instructed to follow the same procedure in their organizations. Apart from making suggestions on these operational measures, an analysis of the non-value added activities is also made, and after elimination of these non-value added activities and the implementation of these suggestions, the timings for the various activities for the proposed scenario are noted and presented in Table 4.

The summation of the time durations in respect of each department is presented in Table 4, and the graphical

Table 4 Lead time for information sharing (Future state)

Process department	Activity time in hrs			
	Forward information sharing (FI)	Return information sharing (RI)	Waiting time	LT
PPC	3.92	2.00		5.92
Engg		3.93		3.93
MMT	5.55	2.73	14.00	22.28
Store		2.73		2.73
Vendor	4.53	3.33	18.00	25.87
Total	14	14.73	32.00	60.73

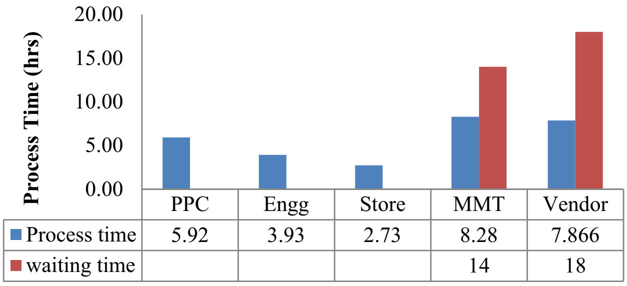

Fig. 7 Lead time for information sharing (Future state)

Table 5 Details of information-sharing process times (Future state)

Process detail	Process time (hrs)
WT-FI	6.0
WT-RI	26.0
PT-FI	14.0
PT-RI	14.7
Process time (Total)	28.7
LT-FI	20.0
LT-RI	40.7
TLT	60.73
Demand increase (car set)	7,151 units

representation of this data is shown in Fig. 7. The summary of the various components of time for the information sharing process is depicted in Table 5, which reveals that the total time consumed in the information sharing process is 60.73 h. It is also estimated that the demand increase is 7,151 units.

Table 5 reveals that the total process time for the information process is 28.7 h comprising 14 h for the forward flow and 14.7 h for the return flow. The total waiting time is observed to be 32 h with 6 h of waiting time in the forward direction and 26 h of waiting time in the return direction. The TLT is found to be 60.7 h, 20.7 h being the LT for the forward flow and 40.7 h for the return flow.

Concerning the demand plan increase, it is observed that the demand quantity is observed to increase at each stage of the process. It is noted that the PPC department increases the demand by 5% more than the customer demand based on the past month's demand plan and actual status, the MMT increased 5% of the demand quantity compared to the PPC plan, due to a lack of inventory accuracy status from in-house store and vendors, and the downstream vendor further increases the material procurement plan by 10% on an average based on the demand plan of Tier-I MMT and also to avail the benefit of bulk quantity. At every stage, the presence of mistrust is observed and this happens because of the procedures being adopted. With the introduction of the changes suggested in the proposed approach of information management, the demand plan increase is found to be reduced. Indeed, with the adoption of the new proposals, the MMT of the case organization follows the PPC demand plan without any increase in demand, whereas the vendor reduced its material procurement plan from 10 to 7% due to the improved demand plan of Tier I MMT. Consequently, the demand increase is observed to get reduced from 12,318 sets to 7,151 sets as against the demand of 57,900 sets from the customer end. To bring out the benefits derived, the current state is compared with the improved future state concerning the activities concerned with the information flow process and the department-wise savings in time, which are presented in Table 6. A summary of the comparison of the information-sharing process in the current and future states is also presented in Table 7.

The future state VSM map drawn as per the improved process times is presented in Fig. 8.

Conclusions

This research study addressed the various kinds of information and information-sharing practices followed in an automobile industry. The wastages and non-value added activities in the information sharing process of an organization

Table 6 Department-wise comparison of process times for the current and future states

Department	Activity time in hrs						Reduction in time	% reduction in time
	Current status			Future status				
	Process time	Waiting time	LT	Process time	Waiting time	LT		
PPC	6.67		6.67	5.92		5.92	0.75	11
Engg	4.58		4.58	3.93		3.93	0.65	14
MMT	15.67	45.50	61.17	8.28	14.00	22.28	38.88	64
Store	9.50		9.50	2.73		2.73	6.77	71
Vendor	13.18	27.00	40.18	7.87	18.00	25.87	14.32	36
Total	49.59		122.10	28.73	32.00	60.73	61.37	50

Table 7 Summary of information-sharing process times for the current and future states

Process detail	Process time (hrs)			% improvement
	Current state	Future state	Improvement	
FI	23.6	14.0	9.6	41
RI	26.0	14.7	11.3	43
Waiting time	72.5	32.0	40.5	56
TLT	122.1	60.7	61.4	50
Demand increase (car set)	12,318	7,151	5,167	42

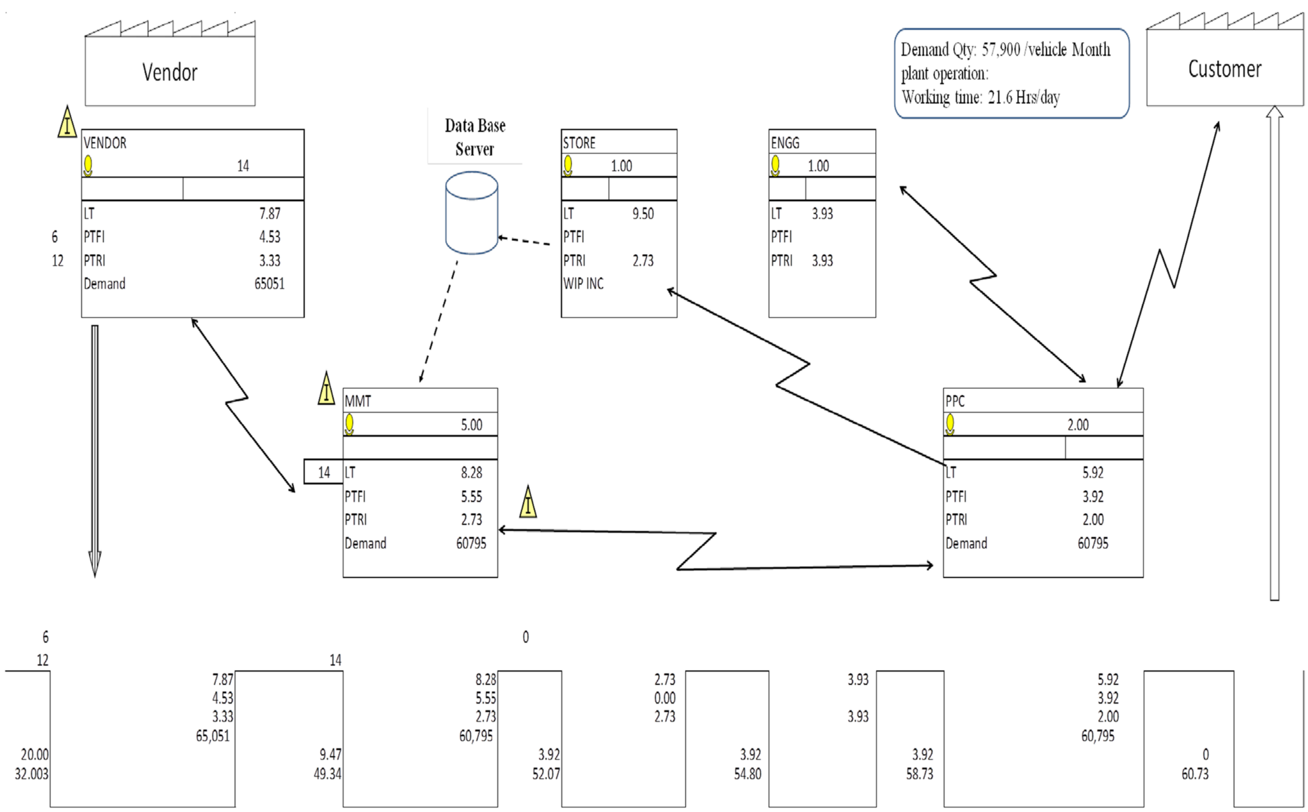

Fig. 8 Future state map

were identified through the VSM technique by comparing the current state with future state maps for the case organization. From the study, it is found that there are some deficiencies such as lack of reply or delayed reply from vendors, inaccurate data of inventory status and schedule of demand plan, inaccurate or unreliable capacity status of vendors (Tier II), inconsistent data format or non-standard data format, ineffectiveness of approval procedure and variation in demand plan. Considerable reductions in process times and waiting times were observed. The processing time for forwarding information flow is reduced by 10 h resulting in a 41% reduction, the same for return information flow is reduced by 11 h resulting in a 43% reduction. Similarly, the waiting time reduction is observed to be 56% and 50%, respectively, for the forward flow and return flow of information. The total lead time is reduced from 122. 1 h to 60.7 h leading to a 50% reduction.

The demand plan increase is found to decrease from 12,318 car sets to 7,151car sets resulting in a 42% reduction. And it is suggested that standard format, which contains the details of the model-wise assembly line control code can be adopted for data transfer and data segregation in all the departments of the case organization as well as all the members of the supply chain. The demand plan, actual production, and inventory status are to be updated weekly during the CFT meetings with the spreadsheets providing details on the volume and mix of daily deliveries, which leads to improvement in information accuracy with transparency.

Furthermore, shift-wise updating of stock position status report by both Tier I and Tier II is required, thereupon on a common data storage location.

Implementation of these proposals has resulted in substantial improvements in the process times with other associated benefits such as the information flow time between the customer and the vendor is reduced by eliminating the non-value added activities, the information sharing between the MMT and the store of the case organization is improved through a reduction in waiting time for the data, due to the regular meetings of CFT the inventory status is updated every week. This study demonstrated that the substantial improvements in the total time taken for information processing can be realized and VSM have been proven to be a powerful tool to eliminate the wastes in the information-sharing process of any organization.

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Declarations

Conflict of interests The authors have no conflicts of interest to declare that are relevant to the content of this article.

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