Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 11 (2017) 838 – 845

Procedia MANUFACTURING

27th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2017, 27-30 June 2017, Modena, Italy

Modeling Supply Chain Performance

Paul Eric Dossou*, Meriem Nachidi

Icam Site de Paris-Sénart, 34 Points de vue, 77127 Lieusaint, France

Abstract

European countries actually adopt industry 4.0 and supply chain 4.0 philosophy. Enterprise modelling methodologies define enterprise as a system, which can integrate new technologies, Internet of things, automation and robotics in collaboration with people. GRAI methodology and its supporting tool GRAIMOD are used for modelling, analysing and improving enterprise supply chain performance. QCD (quality, cost and lead time) criteria are combined (in GRAIMOD) to social, societal and environmental dimensions for improving the company supply chain. This paper presents how lead-time criterion could be implemented for increasing supply chain performance. A real application is given for illustrating the concepts presented.

Peer-review under responsibility of the scientific committee of the 27th International Conference on Flexible Automation and Intelligent Manufacturing

Keywords: Carbon reducing, supply chain mamangement, quality management, knowledge management

1. Introduction

European countries have to adapt themselves to globalization impact on industry. Due to the low cost of workforce in emerging countries, they have to think about how to improve their organization for being more competitive. Then, industry 4.0 and supply chain 4.0 are crucial because of the introduction of new technologies, robots, automation, Internet of things and computer-aided tools in companies for increasing their performance. The question is how to standardize and elaborate processes of improvement and being sure about the result. How to use

* Corresponding author. Tel.: +33-181-141-041;
E-mail address: paul-eric.dossou@icam.fr

Peer-review under responsibility of the scientific committee of the 27th International Conference on Flexible Automation and Intelligent Manufacturing
doi:10.1016/j.promfg.2017.07.186

of the right tool according to company expectations, how to design and implement right technologies? Finally, how to help decision makers in the improvement of their companies?

New technologies are used here for improving company performance in terms of production quality, lead-time and cost management but also carbon and waste management, social, societal and environmental dimensions management. Indeed domains are technological (automation, regulation, robot, cobot, Internet of things, traceability), organizational (lean, 6 Sigma, kanban, MRP implementation), informational (computer aided system, expert system, decision aided system) and adapted to new constraints, enterprise future expectations.

Enterprise modeling appears as one way for solving the problem and giving adapted and structured solutions to companies. GRAI methodology is one of the three main methodologies for enterprise modeling. This methodology is used for analyzing companies technically, organizationally by taking into account human aspects, social, societal and environmental dimensions and for improving enterprise performance. GRAIMOD is a software tool used for improving enterprise performance with GRAI methodology.

This paper focuses on formalisms associated to performance criteria. KPIs are indispensable for measuring an existing system state, and compare it to future system vision. A zoom is made on lead-time criterion for showing how it could be used.

For illustrating and validating concepts and formalisms presented, a real application will be exposed.

2. Methodology and concepts

2.1. GRAI methodology and GRAIMOD

The objective is not to present GRAI methodology (see [1] for more detail on this methodology). In this paper the focus is on the use of GRAIMOD for improving enterprise supply chain [2]. GRAI approach consists in elaborating existing system models, analyzing them and proposing improvement and solutions. During the modeling phase, five models are elaborate. Performance criteria are used for measuring the existing and the future systems.

The performance of a system (supply chain) is improved by finding an optimum by combining criteria. The objective is the use of case-based reasoning, expert systems, multi-agent systems and computer aided tools [3, 4, 5], combined with new technologies for defining the best organization for a company.

Then GRAIMOD is composed of two sub-systems: analysis interface and improvement parts (fig. 1). The detail of modules and interactions is presented in [5]. This paper focuses only on lead-time criterion and defines concept and formalisms elaborated for realizing company performance improvement (according to lead-time criterion).

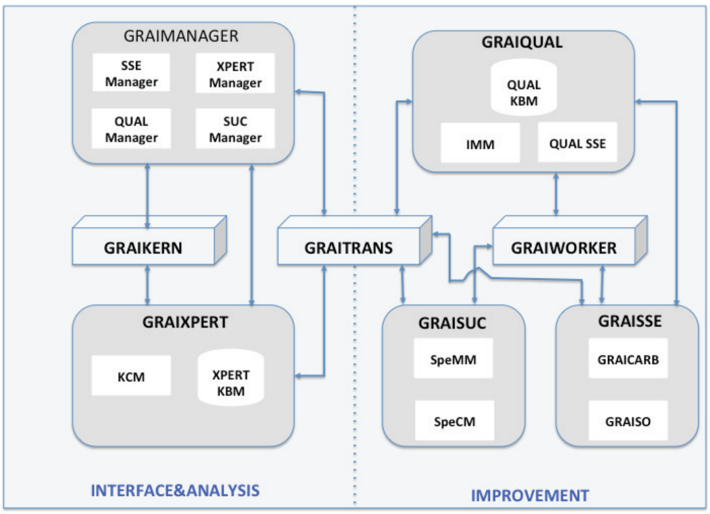

Fig. 1. Structure of GRAIMOD

2.2. New concepts and formalisms

The company supply chain is considered as a system. Theories of design, of systems, and hierarchical systems combined with decomposition reasoning and Case-Based reasoning are used for improving company performance.

Improving this supply chain involves to pay attention about each sub-part, to apply theories and concepts needed for increasing the performance of each part, and to take time for finding coherence between each part.

As presented above, performance criteria are QCD in addition to social, societal and environmental dimension. Each criterion is considered as a combination of sub-criteria. For instance, the quality q of a supply chain (procurement process) could be divided into:

- q_f - quality of suppliers (result of quality functionalities allowing to evaluate suppliers),
- q_p - quality of products (result of quality parameters defined for measuring the product quality),
- q_{pr} - quality of process (result of the use of quality statistical process control or 6 sigma techniques),
- q_s - quality of the system (result of a global quality management defined by using quality management tools on the sub-system)

Indeed, the same analysis could be made on the criterion lead-time. This paper makes a zoom on lead-time criterion. Lead-time associated to a manufacturing process could be defined as following:

- l_p - production cycle lead time
- l_q - time lost because of non quality
- l_t - product transfer time

The problem obtained could be presented as a linear program. Then for optimising the supply chain, it is simple to combine criteria and solving easily the problem [5]. Indeed, the gap with reality is huge. In fact, the observed system (supply chain) is non linear, and sometimes discrete. Then, it is necessary to redefine the problem and to find realistic solutions by using non-linear or discrete formalisms. The idea is to describe the problem as a non-linear one and to solve it with non-linear and discrete methods. Thus, parameters associated to each criterion have not only quantitative properties but also qualitative tools. It means that fuzzy logic is necessary for well defining the problem and finding the appropriate solution.

As explained above, knowing lead-times in a production chain is necessary for improving the global chain performance. Lead-time is a combination of various phenomena and varies nonlinearly with production type, scheduling, human /technical resources and so on. Thus, it is important to find an adequate methodology for representing, predicting and controlling supply chain lead-time in order to improve manufacturer's reputation.

Most of existing works in the literature are limited to develop models for lead-time that can only be used as estimators, those models cannot give more information, for instance: if a predicted lead-time is accepted or not, how it can be used in a control strategy.

In this paper, a model-based control for lead-time is being developed. The use of artificial intelligence-based methods [6, 7] advantages is proposed to predict lead-time model in a manufacturing process. Indeed, these methodologies as fuzzy modeling and artificial neural network have been used widely to handle nonlinearity and complexity inherent in real systems.

Let, $LT_i(x_1, x_2, x_{3,}, u)$ be a daily lead-time function, which represents the output of the manufacturing system, where x_1 is the working time, x_2 is the number of failure, x_3 is the repair time and u is the control variable (fig. 2).

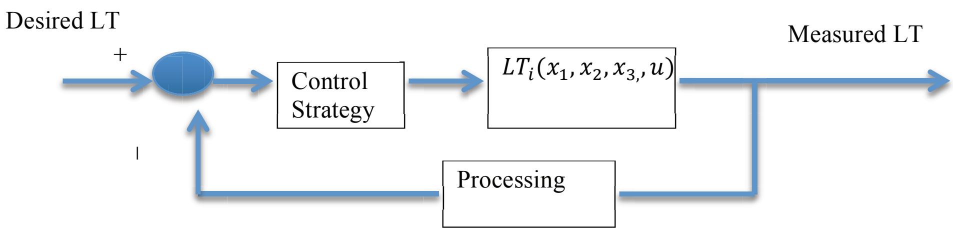

Fig. 2. State feedback control

The use of the following algorithm is proposed to calculate the LT model:

Step 1: Selection of the inputs and outputs of the system. This operation depends on the desired objective which can be: planning control of working time in a given link, integration of a new task or developing strategy control to decrease the lead-time.

Step 2: Process data using regression algorithm. The output is a relationship in the form:

$$LT_i(x_1, x_2, x_{3,}, u) = \alpha_0 + \beta_1 x_1 + \gamma_2 x_2 + \delta_3 x_3 + u$$

Step 3: Calculate the overall model: $LT(x_1, x_2, x_{3,}, u) = \sum_{i=1}^{N} h_i(x_1, x_2, x_3) LT_i$, where N is a finite prediction horizon.

Step 4: Comparison with the actual and estimated Lead-Time. This comparison will generate an error, ε.

Step 5: if $\varepsilon \leq 10^{-4}$, the model is valid and can be used to derive an adequate controller, else , we return to Step 2, to tuning the parameter of regression algorithm.

3. Application

3.1. Context of the company

The example presents the supply chain of a company specialized in body products manufacturing and distribution. The workforce of the enterprise is about 400 people and is growing steadily. The turnover was about 320M€ in 2015. The manufacturing system is 3x8hours organization per day and produces 1,2 million of products per day. This company has increased the production and dispatching levels by obtaining 2 new businesses. Then, it was difficult for the company to satisfy this new challenge because of lead-times and tasks associated to the global supply chain.

The objective of the study was to analyze in detail the supply chain of the company, to pinpoint inconsistencies, find point to improve and propose (and implement) new solutions for improving the enterprise performance.

To increase the company supply chain performance, each function (as sourcing, purchasing, procurement, production, transport, dispatching) has to be optimized. Then the global optimum will be combination of local optimums.

The objective is to increase the level of automation of the supply chain in order to decrease lead-time and to take into account ergonomics for employees. The idea is to reduce **lead-time** on the chain, the quality of the products were not a problem, but the study has to take into account societal and environmental aspects in the definition of new solutions. The company has implemented 14 AGV (Automated Guided Vehicles) systems for managing dispatching of raw materials, semi-products and products from the main storage through the manufacturing system and to the expedition zone. The manufacturing system is composed of one production line and two conditioning lines. The company needs to decrease the time lost by Weighers per day. Actually, it is about 30% of their working time. The AGV flows also have to be optimized: find the right number implying their best utilization, decrease bottlenecks and waiting times, optimize collaboration between forklift drivers and AGVs.

3.2. Illustration of concepts

The use of GRAI methodology, GRAIMOD has been validated for improving the company performance. GRAIMOD was used for modeling the existing manufacturing system. During the modeling and analysis phases, GRAIXpert, GRAIManager and GRAIkern were used for obtaining five models describing the company manufacturing system and finding in detail inconsistencies but also points to improve.

The result of the modeling phase allows to choose the right tools and methods for solving the company problem. According to this specific study, DMAIC (table 1) was chosen for managing the project and lean manufacturing philosophy for optimizing the system. The approach for using these tools is managed by GRAIMOD particularly the improvement part. KPIs defined (Quality, Cost, lead time, carbon reduction, social, societal and environmental aspects) were sub divided into sub-criteria for measuring the existing system and the future system.

This company area was not studied before. Then there was not a reference model of the sector in GRAIMOD tool. Generalization reasoning will be used at the end of the study for transforming this case into a reference model for enriching GRAIMOD reference model base.

Table 1. DMAIC approach for the project

STEPS	TASKS	MEASURES
Define	Definition of requirements and project constraints	100%
	Elaboration of project functional handbook	100%
Measure	Data acquisition & system observation	90%
	Existing modeling	95%
	Model parameterization	90%
Analyze	Statistical Data analysis	90%
	Elaboration of management rules	75%
	Elaboration of performance indicators	70%
	Analysis of existing system	40%
Innovate	Research of improvement scenarios	50%
	Scenarios simulation on Flexsim	0%
	Analysis of potential Gains	0%
Control	Simulation and capitalization learning process	20%
	Education & knowledge learning	
	Respect of company objectives	0%
		0%

The application of previous formalisms allows to define the way of measuring and reducing lead time of the system. For instance, the measure has shown the distribution of forklift drivers and weighing times (fig. 3).

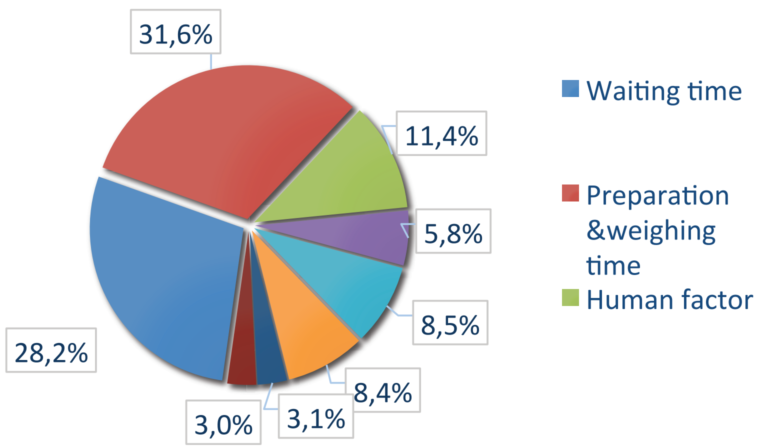

Fig. 3. Average of Weigher working time

The indicators defined for the study according to the lead-time are:

- AGV global working time
- AGV assignment time
- Forklift drivers working time
- Number of weighing per operator
- Waiting time per assignment

The problem of the company was not quality or cost but only lead-time in order to be more productive. Indeed the coherence with the other criteria was required. The idea of the company was to increase the global AGV working time, and reduce waiting time during each AGV assignment. All inconsistencies due to AGV assignment management have to be solved. The weighers and the forklift drivers have to increase their working time.

Then, the use of GRAIMOD and it decomposition reasoning for finding the best solution was required. For instance, to apply the proposed algorithm (chapter 2.2), the waiting time represents the two variables x_2 and x_3, the preparation & weighing time can be represented by the variable x_1. The required result was increasing of x_1 and decreasing of x_2 and x_3. The use of collected data allows to obtain a model that estimates lead-times and to define scenarios for exploiting results.

The deployment of lean manufacturing philosophy allows to define supermarket and borderline procurement organization for improving the system. The supermarket could give freedom (in their work management) to weighers. The AGV working time could be improved by using borderline procurement and by defining processes for reducing the waiting time. Thus, to reduce lead-times, various scenarios have been tested with Flexsim.

3.3. Simulation of the existing system and scenarios

GRAIMOD is associated to a virtual machine in which a software tool could be chosen for simulating supply chain processes. One of these tools is Flexsim. In this case, the use of Flexsim was decided by the enterprise because of internal expertise on this tool. Then, all the existing manufacturing system was simulated (fig.4.).

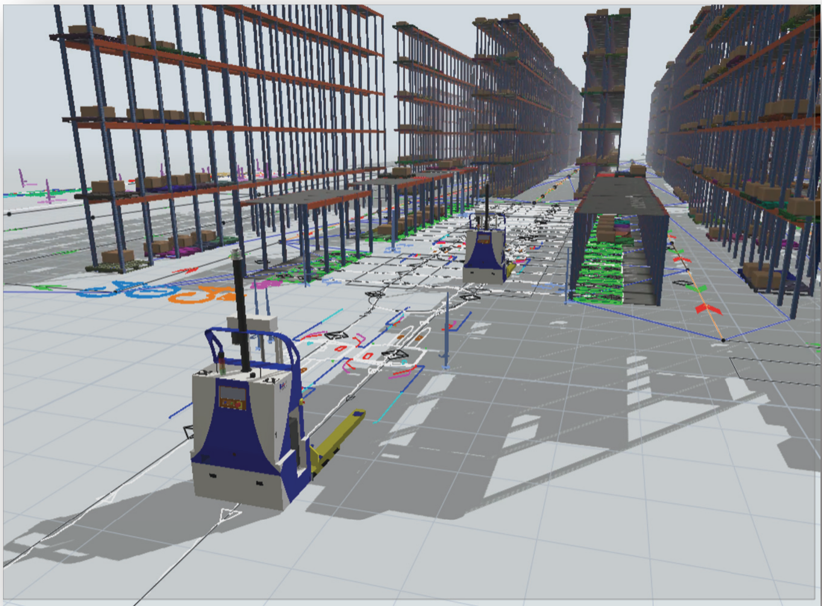

Fig. 4. Simulation of the existing system with Flexsim

A focus was made on the AGV area in order to know exactly how to optimize their functioning. Real data were entered in the system and it was decided to realize simulation with less than 5% of incertitude with the real system. The objective was to furnish and test scenarios on the simulating system for measuring the impact of changes and decisions due to the study on the system.

The existing organization was based on push flows with programing and planning elaborated by using forecast. Lean manufacturing approach was used for future organizations. For instance, in the existing organization the bottleneck was created by AGV flows. The weighers had to call raw materials and wait for the AGVs. Then each assignment was performed by an AGV, without relation with other assignments that could be exploited simultaneously. It means that AGV will take a product for one weigher, waits for taking the rest back for the raw material station, and goes again just near the previous weigher for putting the rest of product to the new weigher.

Indicators defined previously were used for measuring the potential impact on the system and furnishing an idea of how proposed solutions could be implemented for increasing the company performance.

3.4. Analysis of results

Each simulation scenario was elaborated, implemented, tested in flexsim and the results had validated new proposed solutions. For instance, according to the reduction of weighers waiting time, the idea was to test how to reduce this time with our propositions. The following figure presents results of scenarios with the reduction of the waiting time (Fig.5.). The measured parameters are the increasing of weighers production, pallets on time, preparation time and weighing according to scenarios.

The scenario 4 is the best one and allows to increase the number of weighing and to decrease the weighers waiting time. This scenario describes a use of supermarket and steam room for facilitating interaction between AGV, weighers and forklift drivers.

Scenarios / Indicators	N°0 – Existing organization	N° 1 – Organization with supermarket	N° 2 – organization steam room	N° 3 – organization with supermarket and steam room : list 1	N° 4 – organization with supermarket and stem room : List 2	N°5 – organization N4 with 13 AGVs	N° 6 –organization N°4 with 15 AGVs
Pallets on time	19,7	19,4	19	19,1	19,2	17,7	18,8
Preparation time and weighing	31,06 %	33,06 %	34,95 %	0%	0%	0%	0%
Number of weighing	4869	5004	5257	5263	**5314**	4966	5200

Fig. 5. Results of scenarios

The gain of productivity (number of weighing) increased from 4869 to 5314. The percentage is equal to 9,14%. The economical dimension of this implementation was calculated and the ROI (Return on investment) was also deduced. Then a comparison is made with the gain of productivity and the company has chosen to implement this scenario.

Indeed, the AGV waiting time was high, due to circulation queue. For example, AGVs have to pass a gate (with a door), before accessing to the weighing zone. One AGV could be stopped because the door is not open. Then all following AGVs would be stopped too. The solution implemented was to put the supermarket just before the door. The advantage is that the reduction of AGV waiting time was effective. The weighers were more self-sufficient with this new organization. They could come to the supermarket and take products to be prepared for the production phase. The implementation of a steam room allows to prepare one phase of products before the weighing; then the weighers could spend more time on additional tasks.

Concepts developed for lead-time optimization and the use of GRAIMOD have clearly validated the improvement of the company. The use of simulation has facilitated determination of the most adapted solution for this company. The idea of combining improvement, modelling, and simulation, decision aided tools is great and validated. Concepts defined for obtaining lead-time optimization are also validated and the gap with reality was less than 5%. The company has invested for implementing the solution 4 and we are waiting for the real results of last improvements.

4. Conclusion and perspectives

In this paper, new concepts and formalisms on lead-time optimization (associated to GRAIMOD) are presented. Decomposition reasoning is applied to performance criteria and a zoom is made on lead-time for defining how to improve lead-time on the supply chain. The use of a non-linear approach for improving lead time has been presented. Then, an application has been given for illustrating presented concepts and showing the impact of the elaborated theory on a real SME. Performance indicators were defined for measuring performance improvement.

Real difficulties for being competitive on the market allow companies to reorganize and improve themselves in order to be innovative, adapted to future challenges. Their supply chain needs to be reminded and has to integrate all new technologies. Supply chain 4.0 integrates use of Internet of things, traceability, robot, cobot, software tools, cloud computing. Then, the company supply chain performance improvement is difficult but necessary for being more efficient in the future. GRAI methodology has advantage to define a framework and a method for realizing this changes and GRAIMOD the software tool supporting this methodology corresponds to an operational and user-friendly tool. Concepts developed in this paper for lead-time will be extended to the rest of criteria in order to show clearly how the company performance could be increased systematically and automatically by using GRAIMOD.

References

[1] G. Doumeingts, Y. Ducq, Enterprise Modeling techniques to improve Enterprise Performances, The International Conference of Concurrent Enterprising: ICE'99, The Hague, The Netherlands, 1999.
[2] P. E. Dossou, P. Mitchell, Building Reference Models in a GRAI environment for Logistics and Distribution Companies, FAIM2015, Wolverhampton, UK G.
[3] A. Aamodt, Case-Based Reasoning: foundational issues, methodological variations, and system approaches. Artificial Intelligence Communications, 7, (1), 39-59, 1994
[4] D. C. Brown, B. Chandrasekaran: Expert system for a class of mechanical design activities. Knowledge Engineering in CAD, Elsevier, Amsterdam, 1985
[5] P. E. Dossou, P. Pawlewski, P. Mitchell, The use of Multi-agent Systems for Improving a Logistic Platform in a GRAI Environment, Springer, pp126-135, 2015.
[6] Nachidi M, Benzaouia A, Tadeo F, Rami MA. LMI-based approach for output- feedback stabilization for discrete time Takagi–Sugeno systems. IEEE Trans Fuzzy Syst 2008;16:1188–96.
[7] Abraham, A. and Nath, B. A. (2001). Neuro-fuzzy Approach for Modeling Electricity Demand in Victoria. Applied Soft Computing, 1, 127–138.