VIENNA 2018 TRA
A digital era for transport
solutions for society, economy and environment

Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria

Fluvial transportation as alternative solution for optimizing restaurant waste management

Paul-Eric Dossou a,b *

[a] *Université Paris-Est, AME, SPLOTT, IFSTTAR, F-77447 Marne-la-Vallée, France*
[b] *ICAM, site of Paris-Sénart, 34 Points de vue, 77127, Lieusaint, France*

Abstract

The population density in European cities and the increasing of car flows are the main reason of bottlenecks, congestions in cities and disaggregation of quality of life in these cities. Road transportation is not the best way for respecting environmental improvements. Cities like Paris, take political decisions for decreasing this high level of road transportation and changing gasoil consumption. Economic advantages for alternative to road transportation have to be shown to companies in order to accelerate their switching decision. This paper focuses on the optimization of restaurant waste management by using fluvial transportation. The idea is to adapt complex systems modeling to this case and show how this activity sector companies could be competitive. Formalisms and tools of GRAI methodology has been used for elaborating appropriated concepts to this sector optimization. An example integrating real data (with a simulation by using Anylogic tool) will be presented for illustrating theoretical propositions.

Keywords: waste management; performance criteria; cost; quality; lead time; transport optimization; energy and carbon management; simulation.

* Corresponding author. Paul-Eric Dossou Tel.: +33 181141043
E-mail address: paul-eric.dossou@icam.fr

1. Introduction

The population of the region of Paris is about 12 million (2,5 millions inside Paris). The same situation could be observed in other European cities: 3 million people in Roma, 3,4 million in Madrid etc. Car flows are important in these areas. The quality of life needs to be improved. The strong density of population is the cause of traffics and congestions. The consequence is a high level of pollution and noises. Public transportation is one solution for decreasing the traffic. Sustainable propositions are already made by city majors for solving this difficult problem. For instance, in London cars circulation is strongly restricted. In Paris, car speeds are decreased and an urban mobility plan is being deployed for increasing the quality of life in the city. Diesel Trucks circulation will be forbidden in 2020. Then, logistics companies have to reorganize themselves for continuing products delivery in Paris. These city policies are approved by European commission, and H2020 programs. Then, this desire of local, national and European authorities to encourage people and companies to improve their use of road transportation is clearly shown. For accelerating the decreasing of using road transportation by companies, economic advantages of alternative solutions have to be valorized. In this global sustainable policy, one alternative way is the use of fluvial transportation for improving cars flows and decreasing congestions in cities. Indeed, in Hamburg the use of boat as public transport is one kind of fluvial utilization. The idea presented in this paper is the use of fluvial transportation for managing waste of restaurant, people and companies.
This paper presents concepts for modeling complex systems. Formalisms elaborated are based on GRAI Methodology. GRAI Methodology is one of the three main methodologies of enterprise modelling (with PERA and CIMOSA). The structure of GRAIMOD a tool being developed for supporting this methodology will be explained. The use of this tool for validating alternative solution will be shown. Finally, an illustration will be presented. This example is about the use of Seine for transporting waste around Paris. Anylogic simulation tool will be used by integrating real data for showing the efficiency of the proposed alternative solution. The idea is to be able to measure impact of this solution according to performance criteria (cost, lead time, quality, social, societal and environmental dimensions).

2. Literature on enterprise modelling

Three methodologies are mainly used for modelling companies: CIMOSA, PERA and GRAI. CIMOSA (Computer Integrated Manufacturing Open System Architecture) as described in Jorysz and Vernadat (1990) is a methodology developed in the frame of ESPRIT a European project. It is based on an architecture for describing functionalities and behaviors of production systems. The strength of this methodology is the structural architecture based on three levels: requirement definition, design specifications and implementation description. The method is more descriptive than prescriptive. PERA (Purdue Enterprise Reference Architecture) is used for describing in details steps of the life cycle of a project from initial requirement to the end of the project. This approach developed in University of Purdue by Williams (1994) identifies a functional analysis, a functional design, a detailed design, development and implementation. The strength of this method is the human place in the heart of any modelling. GRAI methodology insists on both aspects explored by the previous methodologies for enterprise performance improvement: structural and human aspects. Indeed, a company could be analyzed according to five models (functional view, physical model, informational model, process view, and decisional model). Four formalisms are used for elaborating these models:

- Actigramme for functional view and physical model
- Extended Actigramme for process view
- Class diagram of UML (Unified Modeling Language) for informational model
- And GRAIgrid in addition to GRAInets for decisional model.

GRAI methodology is used for enterprise modelling as described in Doumeingts et al. (1999). The approach (see Fig. 1) associated to this methodology is based on five steps:

- An initialization phase for acquiring the company context in addition to requirements and design objectives.
- A modeling phase for describing existing system
- An analyzing phase for detecting inconsistencies, finding strengths and weaknesses, and measuring performance of existing system.
- A design phase for elaborating the future system: new organization of the company and evaluating performance of the new system.
- An implementation phase for deployment of the new system.

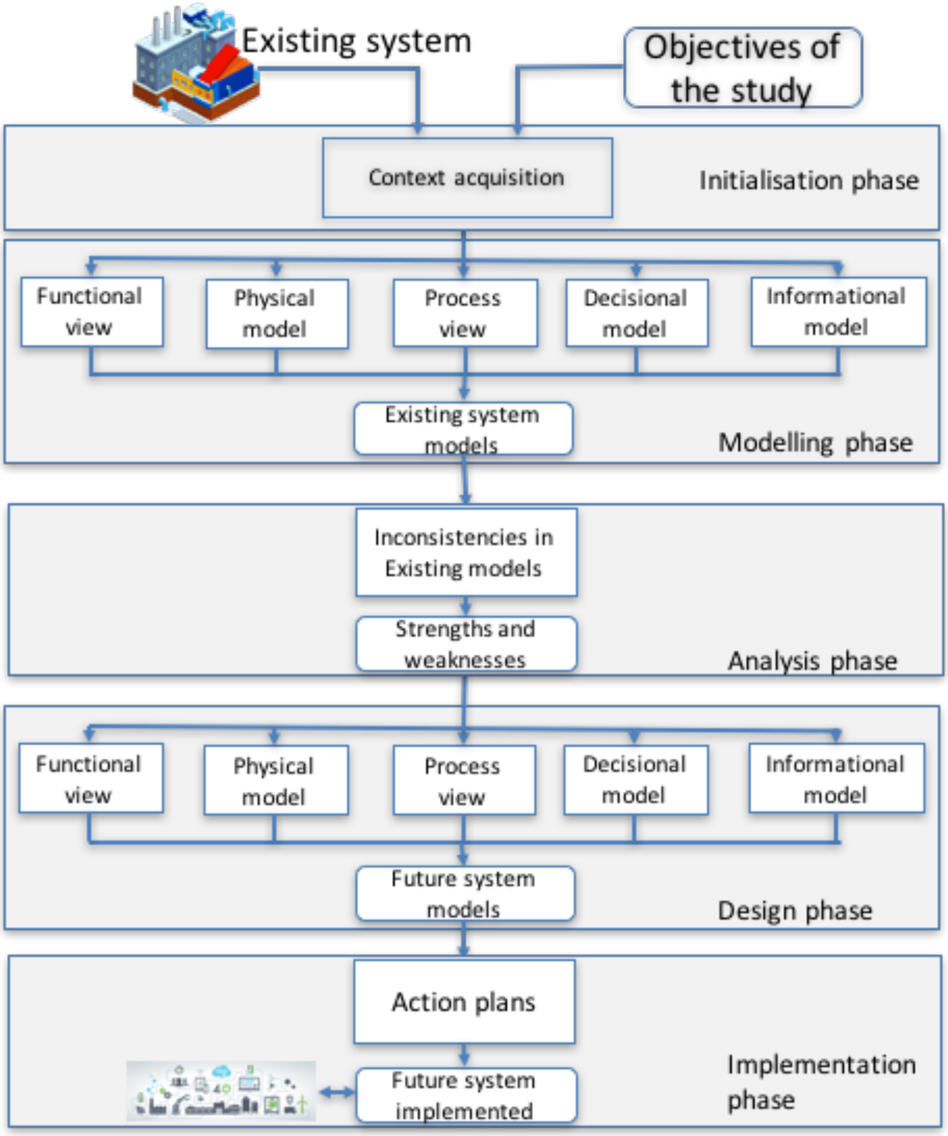

Fig. 1 GRAI Approach

Concepts of this methodology are based on theory of systems. A company could be considered as a complex system as presented in Fig.2. This complexity implies a high level of knowledge management in order to find the best way of performance improvement. It is impossible to have a perfect mastery of all companies.

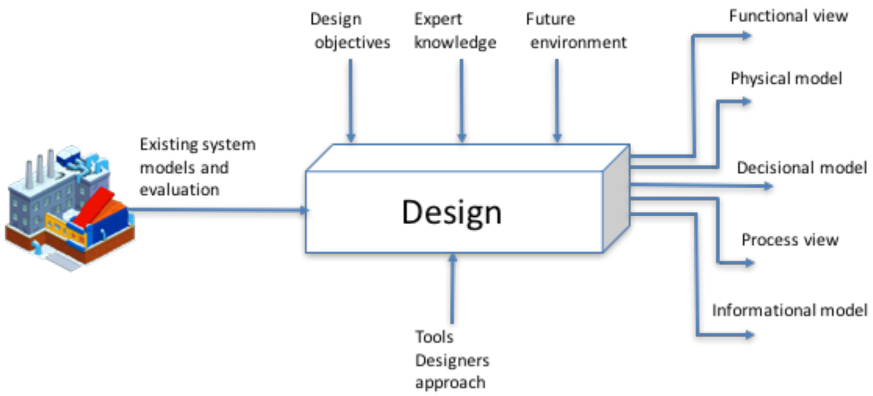

Fig. 2 company as a complex system

The use of a computer aided tool (hybrid expert system) is required for being able to improve performance of any company as presented in Dossou (2003). GRAIMOD is a software tool being developed in Icam for supporting GRAI methodology and offering to companies of any activity domain a way to improve their performance. for elaborating this tool, three kinds of knowledge were elaborated:

- Rules mainly destined to the expert system and the analysis phase
- Old cases used during the design phase and based on CBR (Case Based Reasoning)
- And reference models based on generalization and particularization reasoning

The left part of the architecture of GRAIMOD as shown in Fig.3 is destined to graphic representation and analysis of companies. The right side corresponds to modules used for improving enterprises as explained in Dossou (2015).

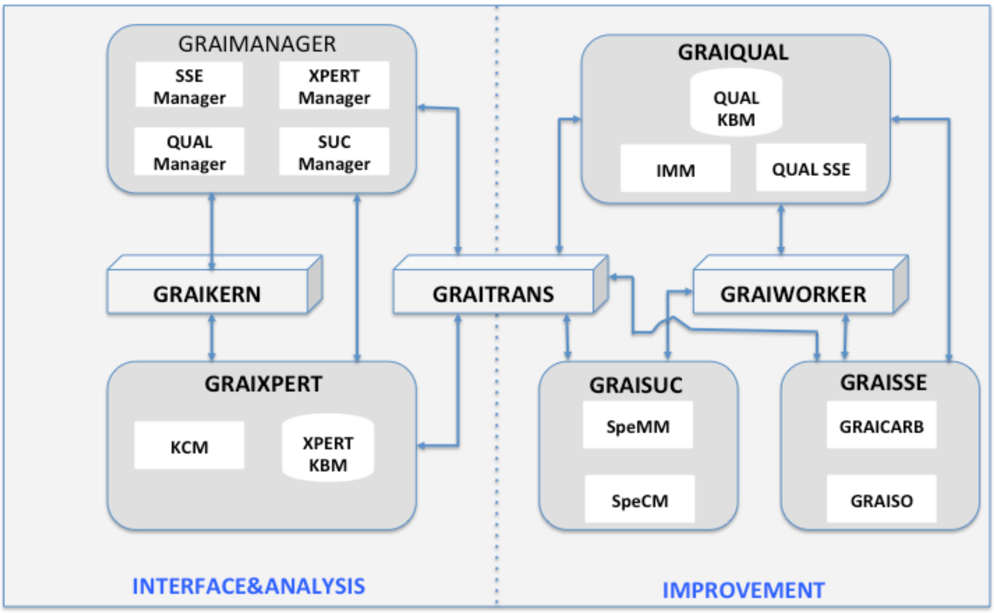

Fig. 3 architecture of GRAIMOD

In the module GRAIXPERT, an expert system of the tool, reference models are capitalized. Then according the activity domain of the company, a reference model could be extracted and used for improving the company performance. For improving transport companies, a reference model was defined for this domain. The module GRAISSE of GRAIMOD is used for suggesting ways of improvement according to carbon reduction and corporate social responsibility.
Thus, the idea is to use these modules of GRAIMOD for defining optimized alternative solution to road transportation.

3. Fluvial transportation: an ecological alternative solution to road transportation

GRAI methodology and GRAIMOD could be used for improving company transport. Indeed, the system "enterprise" could be decomposed into sub-systems according to its functions. The improvement of the system is a combination of sub-systems according to points of view of GRAI methodology (Dossou, 2013). A reference model is defined for company transport. This reference model could be used as the ideal organization of company transport.
Then, this organisation could be adapted according to each enterprise context and objectives. for optimising company transport, the existing system has to be defined according to GRAI methodology points of view. Then, these models will be analysed, and future models will be elaborated.
Thus, performance criteria are defined for measuring the state of an enterprise (existing system and future system). Optimization of the company transport corresponds to find an optimum by combing criteria like cost, quality, lead time but also social, societal and environment dimensions.
In European cities (and around), many companies are implemented and their impact on the city life is important. for instance, it is benefit in terms of employment but the footprint or the pollution are disaster.
Then many problems could be noticed in a city according to urban logistics and transport:

- problem of pollution due to quantity of cars and trucks (but also manufacturing)
- problem of density of traffic, congestion and car flows management
- problem of greenhouse gas
- and desire of local authorities to reduce negative environmental impact in their city (no diesel in Paris in 2020, norms and rules).

The response to these problems could be the use of algorithms (linear programs, etc.) for finding the optimum and continuing with road transportation. But in this case, all performance criteria (quality, cost, lead time, carbon management, social, societal and environmental dimensions) defined in the frame of GRAI methodology are not used.

Indeed, if Tr is a vector corresponding to products transportation in a company, and Tr_F, Tr_P, Tr_I, Tr_{Pr} and Tr_D vector represent respectively physical, functional, informational, process and decisional points of view of the transport system, then:

$$Tr = \propto * Tr_F + \beta * Tr_P + \gamma * Tr_I + \delta * Tr_{Pr} + \varepsilon * Tr_D \qquad (1)$$

This global transport model allows to describe in detail the transport existing system and then to improve it. The optimum is not only algorithmic solution integrating only a part of criteria. This optimum is defined by a combination of the parameters representing each company performance criterion as defined in the previous chapter and. Tr_Q corresponds to quality optimizing impact and Tr_C, Tr_{Lt}, Tr_{CSSE}, respectively to cost, lead time, carbon management, social, societal and environmental optimizing impacts. Then the global transport optimum is shown in Fig. 4:

$$Tr = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} X \begin{bmatrix} Tr_Q \\ Tr_C \\ Tr_{Lt} \\ Tr_{CSSE} \end{bmatrix}$$

Fig. 4 combination of transport parameters

Thus, Transport optimization could be considered as a progressive refinement of the previous equation for obtaining situations adapted to the company problem. The company environment is important for finding the best solution. Indeed, parameters as city congestion management, smart city implementation, quality of life increasing, etc. have to be integrated in the solution of the system. GRAIMOD allows to model the company transport according to equation (1): use of GRAKERN and GRAIXPERT for elaborating models. This tool is also used for analyzing the company transport inconsistencies in order to find strengths and weaknesses: use of diagnosis rules contained in GRAIXPERT. Finally, the company transport could be improved by designing the optimum and realizing progressive refinement: use of cases and transport reference model defined in GRAIXPERT and use of GRAIQUAL, GRAISUC and GRAISSE for optimizing the system. Each criterion used in this optimization could be divided into sub-criteria for analyzing in detail each aspect of the design. For instance, the optimum corresponding to quality has to integrate quality of product transported, quality of the transport system, quality the company suppliers, quality of the management process, etc.

4. Case of Restaurant Waste management

Due to congestion, circulation in main European cities is difficult. The following example proposed a solution for decreasing car flows, but also managing waste and optimizing transport of recycling companies. This example is focused on restaurants in Paris. The idea is to study in detail how to use fluvial transportation for waste management. The current regulation in France implies that restaurant have to treat their waste especially greasy waste. Trucks are specially used for transporting this grease from the restaurants to treatment manufacturing. A detailed study was realized by using GRAIMOD (GRAIKERN and GRAIXPERT) tool for modelling existing restaurants in Paris and their requirements. Three kinds of restauration could be observed in Paris: traditional, fast food and collective restaurants. The panel of restaurants defined for this study was about 250. But only 58 have accepted to participate actively. The others were interested by the results but did not have time for participating. The first step was to know exactly their needs in terms of greasy waste evacuation (capacity of their storage). Then, interviews of each of the 58 restaurants were realized and their models according to GRAI methodology were elaborated in GRAIMOD. The following table presents the repartition of these restaurants.

Table 1. Number of meals/day in panel traditional restaurants

Size of traditional restaurant	Number of the panel	Percentage	Mean number of meals / day
> 350 meals/day	5	10%	402
between 200 et 350 meals/day	10	21%	250
< 200 meals/day	33	69%	95
Total	58	100%	

Data collected and capitalized in GRAIMOD were used for defining a general view of restaurants in Paris. An extrapolation could be made on all restaurant allows to define the quantity of greasy waste to transport per day.

Table 2. Estimation of number of meals/day in traditional restaurants

Size of traditional restaurant	Percentage	Estimation of the number of restaurant	Meals / day
> 350 meals / day	10%	297	174 067
entre 200 et 350 meals /day	21%	624	156 000
< 200 meals / day	69%	2 050	194 750
Total	100%	2 961	524 817

The quantity of meals gives an idea of greasy waste to send to waste treatment manufacturing.

Table 3. Quantity of greasy waste per meals in restaurants

Type of restaurants	Meals / day	Quantity of greasy waste (tones / day)
Traditional restaurants	524 817	20,1
Fast foods	90 000	3,6
Collective restaurants	394 600	15,8
Total	1 009 417	40,4

Indeed, a study of companies transporting greasy waste was made in the same time. Their interest for this study was evident and they expressed their expectations of results. GRAIMOD was also used for making their interviews. The capacity of trucks is generally 3 cubic meters. The recycling manufacturing are located outside of Paris (Bonneuil and Ecquevilly). Indeed, trucks have to support traffic all day for bringing waste to the recycling companies. Then a survey had been done on transport companies and shown that their main economical constraint is time lost in traffic. The following table estimated average time and costs associated to trucks from each area of Paris to the recycling manufacturing.

Table 4. average time and cost by road transportation

	Bonneuil sur Marne	
	Time	**Cost**
Bercy	1h09	13,83 €
Gare du Nord	2h05	22,22 €
Porte de Bagnolet	1h32	18,83 €
Saint Lazare	1h59	18,27 €
Porte de St Cloud	2h05	27,64 €
Gare Montparnasse	2h10	21,58 €
Chatelet les halles	1h49	15,39 €
Arc de triomphe	2h30	31,77 €
Place d'Italie	1h18	14,19 €
Average	**1h51**	**20,41 €**

Thus, a truck could only have made 2 rounds per day (maximum 3) because of time lost during waste transport. Many restaurants had to wait for a long time before having their greasy waste cistern empty as seen in Fig. 5.

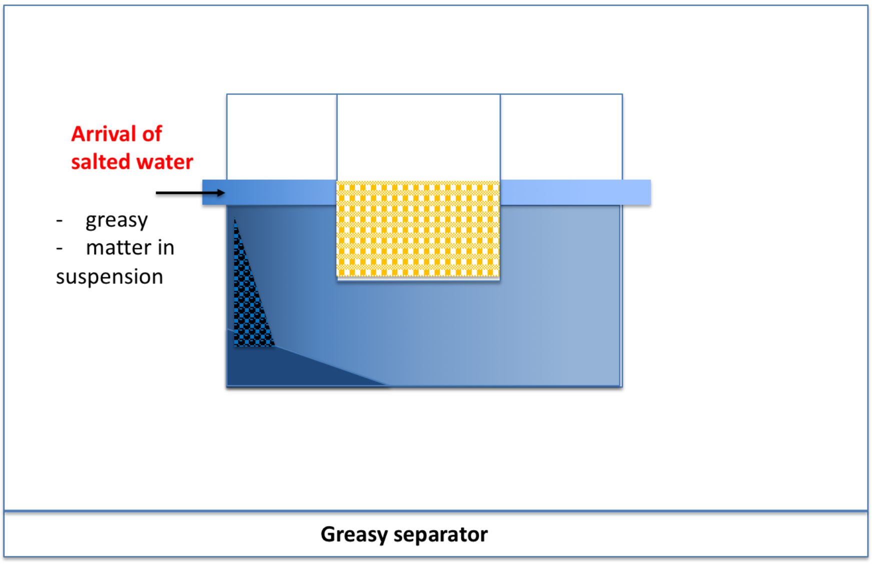

Fig.5 Greasy cistern

For the analysis phase of GRAI methodology, rules contained in GRAIXPERT were used for finding inconsistencies in the existing organization. Points to improve were pointed out. For instance, trucks spent a lot of time in traffic in Paris. The number of tours for transporting waste was reduced by these congestions.
For the design phase of GRAI methodology, GRAIXPERT, GRAIQUAL and GRAISSE were used for proposing solutions in order to improve company performances (cost, lead time and carbon reducing) and to define a new organization of the sector.
The use of fluvial transportation would be a great opportunity to all business partners and collectivities. Indeed, local authorities would be happy because of road transportation reduction and the use of the Seine for going around Paris, restaurants will have a better greasy waste management, and recycling transport companies will reduce their cost and environmental footprint.
The alternative solution is to use recycling trucks for collecting greasy waste but instead of bringing them directly to recycling manufacturing companies, to define points on the Seine as shown in Fig. 6, for receiving waste and sending them to these companies by barge.

Fig. 6 comparison between alternative solution and road transportation

Anylogic tool was used for realizing simulation of the existing situation and for simulating the alternative solution. Simulation models and results will be presented during TRA2018 conference. Real data acquired with the survey were integrated in this simulation for elaborating the existing model as seen in Fig. 7. This model was analyzed and a dashboard were done for measuring the actual state according to performance criteria proposed in GRAIMOD: Quality, Cost, Lead time, Social, Societal and Environmental dimensions. The optimization was done according to the alternative solution chosen and then a new simulation was elaborated for this new model.

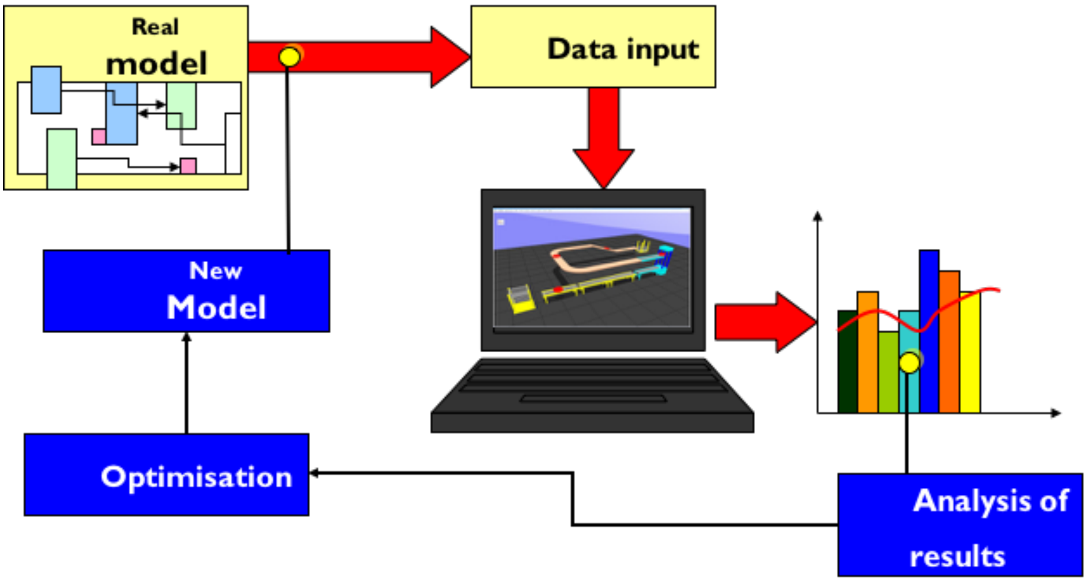

Fig.7 simulation process

The smaller distance is Bonneuil manufacturing as presented in table 5. Then this hypothesis was chosen for calculating environmental impact. Each truck had to make 45,56km per round. Each truck with charge produces 1,186kg of CO2 per km (according to Ademe an environmental French organism), and each empty truck produces 0.84kg of CO2 per km. The total per truck from Paris to Bonneuil is about 45, 8 kg of CO2 per round. Each truck could transport 5 tones of greasy waste per round (estimation). For evacuating 250 tons of waste, 2289,4 kg of CO2 are generated. The annual estimation is about 14710 tones of greasy waste evacuated from Paris and they generated 134,7 tones of CO2 per year. Table 6 presents the improvement obtained in CO2 reduction by using our solution.

Table 5. distance to recycling waste manufacturing companies

Area	Ecopur Bonneuil	Ecopur Ecquevilly
	Distance	Distance
Bercy	14km	49km
Gare du Nord	20km	40km
Porte de Bagnolet	18km	47km
Saint Lazare	25km	36km
Porte de St Cloud	36km	37km
Gare Montparnasse	29km	43km
Chatelet les halles	19km	40km
Arc de triomphe	25km	34km
Place d'Italie	19km	41km
Average	22.78km	40.78km

Table 6. Comparison between actual and alternative solutions

Data	Quai d'Ivry	Port de l'arsenal	Port de la bourdonnais	Actual solution
Road Distance (in km)	6,8	5,0	6,4	22,8
Fluvial Distance (in km)	11,0	14,0	19,5	0
CO2 emission per truck (in kg for 5t)	13,6	10,0	12,8	45,8
C02 emission per barge (in kg for 250t)	165,6	210,7	293,5	0
global CO2 emission (in kg for 250t)	846,9	709,2	933,7	2289,4
Annual CO2 emission (in tones)	49,8	41,7	54,9	134,7
Reduction rate of emission	2,70	3,23	2,45	NA
CO2 improvement (in tones/year)	84,9	93,0	79,8	NA

Table 7. Gain of alternative solution

	Boneuil sur Marne		**Quai d'ivry**		**Port de l'arsenal**		**Port de la bourdonnais**	
	Time	**Price**	**Time**	**Price**	**Time**	**Price**	**Time**	**Price**
Bercy	1h09	13,83 €	0h23	2,22 €	0h54	9,43 €	1h24	4,12 €
Gare du Nord	2h05	22,22 €	1h17	10,32 €	1h29	12,96 €	1h42	3,98 €
Porte de Bagnolet	1h32	18,83 €	0h46	7,42 €	1h25	15,79 €	2h23	17,80 €
Saint Lazare	1h59	18,27 €	1h13	6,71 €	1h11	8,15 €	1h11	1,54 €
Porte de St Cloud	2h05	27,64 €	1h19	16,25 €	0h39	6,44 €	1h04	1,68 €
Gare Montparnasse	2h10	21,58 €	1h32	11,45 €	0h40	1,69 €	1h19	1,89 €
Chatelet les halles	1h49	15,39 €	0h57	4,27 €	0h54	3,61 €	1h27	2,08 €
Arc de triomphe	2h30	31,77 €	1h46	20,21 €	1h05	11,59 €	1h23	1,28 €
Place d'Italie	1h18	14,19 €	0h31	2,70 €	0h41	4,69 €	1h23	5,14 €
Average	**1h51**	**20,41 €**	**0h54**	**9,06 €**	**0h44**	**8,26 €**	**1h08**	**4,39 €**
Gain	**NA**	**NA**	**0h57**	**11,35 €**	**1h07**	**12,15 €**	**0h43**	**16,02 €**
Global Gain per company / round	**NA**	**NA**		**21,61€**		**24,21€**		**23,76€**

According to QCD and CSSE criteria, the gain could be measured for a company as presented in table 7. Then, Transport time would be reduced. It implies that the company would have possibility to increase rounds and logically his turnover and customer satisfaction. It is also opportunity to optimize cost by reducing carburant (and optimizing the number of truck drivers).

In terms of quality, quality of service would be increased. Then the gain for restaurant is evident. The social aspect would also be taking into account because drivers would not spend a lot of time in traffics.

The alternative solution is adapted to Paris city major desire (reduction of road traffic and waste management), European commission expectations, and our planet preservation. This study is being used for defining a reference model for this sector and capitalizing this new model in GRAIMOD.

Main performance indicators used in GRAI methodology for improving company performance has shown that this idea is pertinent and a good alternative to road transportation.

The implementation phase of GRAI methodology would be realized at the end of the study. The benefits of this new organization have to be shown to companies and restaurant for convincing them to change their actual organization. Then, implementation and experimentation would be done.

5. Conclusion and perspectives

This paper focuses on enterprise modelling and company performance improvement. A methodology (GRAI) and a supporting tool (GRAIMOD) based on theory of system for improving companies have been presented. Concepts have been adapted to transport area by taking into account companies environment (city and local authorities). A company performance has to be optimised by using main criteria cost, quality and lead time (QCD) but also social, societal and environmental dimensions (including carbon management).
Then, this paper presents concepts for optimizing companies transport with alternative solutions to road, but also reducing cars flows, congestions, for cities. The idea presented is to use fluvial transportation for bringing waste to recycling manufacturing companies. This idea could be used in all cities having a river. In Hambourg city, fluvial transportation is already used for mobility, then it could be interesting to deploy in addition this new possibility. The impact on cities would be immediate.
The future work will be to generalize this example and testing it on European cities. Many perspectives could be explored. For instance, may be during fluvial transportation greasy waste could be pre-treated. Then, barges have to be elaborated for realising this pre-treatment. This kind of transport could be extended to other waste. Constraints and norms have to be integrated in the study. For instance, the height of the barge (because of bridge in Paris) would be important and would limited barge capacity.
Fluvial transportation could be a good alternative to road transportation for making cities more sustainable. This solution could also be combined with railway transportation. Optimization solutions based on railway transportation as proposed in Nierat (1997), had already many experimentations but are not well-developed in France. In Paris region, a combination between transportation on the seine and on railway will decrease cars flow and road transportation.

6. References

Doumeingts, G., Ducq,Y., Vallespir, B., Kleinhans, S., 2000. 'Production management and enterprise modelling' – Computer in Industry 42 (2000) pp245-263, 2000.

Dossou, P.E., 2003. 'Modélisation des raisonnements pour l'aide à la conception des systèmes de production', Thèse de doctorat, LAP GRAI, Université Bordeaux 1, France, 2003.

Dossou, P.E., 2010. 'Carbon Reduction: New criteria of supply chain performance' FAIM 2010, Oakland, East Bay, USA, 2010

Dossou, P.E., Mitchell, P., 2013. 'Elaboration of reference models for improving enterprise performance', Advances in Sustainable and Competitive Manufacturing Systems, Lecture notes in Mechanical engineering, Springer, pp. 899-910, 2013.

Dossou, P.E., Mitchell, P., 2015. Building Reference Models in a GRAI environment for Logistics and Distribution Companies, FAIM2015, Wolverhampton, UK

Dossou, P.E., Nachidi, M. ,2017. Modeling Supply Chain Performance, in Procedia Manufacturing 11C (2017), pp838-845, ELSEVIER,

Jorysz, H. R., Vernadat, F.B., 1990. 'CIM-OSA, part 1: total enterprise modelling and the function view' in International Journal Integrated Manufacturing, Vol. 3 and 4, pp 144-156

Jorysz, H. R., Vernadat, F.B., 1990. 'CIM-OSA, part 2: Information view' in International Journal Integrated Manufacturing, Vol. 3 and 4, pp 157-157

Niérat, P., (1997). 'Market area on rail-truck terminals: pertinence of the spatial theory'- Transpn Rex.-A, Vol 31, N°2, pp109-127, 1997, ELSEVIER

Williams, Th. J., 1994. 'The Purdue enterprise reference architecture', Computer in Industry, Vol. 24 (2) pp141-158