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The robustness of the tour planning face to risks of road freight transport

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Abstract—Currently, over 90% of goods are transported by road terrestrial mode. To progress, companies of Road Freight Transport sector (RFT) are subject to a number of issues, whether economic, regulatory, environmental, societal, occupational health and safety ... The planner has a crucial role in achieving these challenges, it is he who undertakes the construction method of the tours, for the future of the company. Thus he bears a heavy responsibility on his shoulders. Its ability to integrate the company's constraints and to master the balance between these issues in the construction of tour is vital. However a list of risks is potentially present and can affect his planning. This lack of vision about risks impact prevents him to achieve his mission. Thus we propose in this article a mean to qualify the tours generated in relation to the issues mentioned but also in terms of potential hazards that could come impair the quality of tours. In this article, we propose an evaluation process of road transport of goods tours and an indicator to measure the robustness of touring.

Index Terms—risk, assessment, decision, tour, robustness

I. INTRODUCTION

Nowadays, more than 90% of goods are conveyed by road. Road Freight Transport (RFT) companies therefore embody a sector of capital importance to the French economy; they represent an annual turnover of 44 billion euros, which is generated by more than 37,200 companies (more than 90% of companies in this sector are SMEs/VSEs with less than 50 employees) and roughly 420,000 employees. This sector is characterized by strong competition and growing pressure from customers and suppliers, tight delivery times, exacerbated flexibility, etc. (economic stakes). RFT companies are also subjected to specific national and community standards and regulations (regulatory and environmental stakes). In parallel, they are required to fulfil performance duties in terms of preventing risks of occupational accidents and diseases (article L4121-1 of the French labor code) (occupational health-safety issues). Simultaneous consideration of these three obligations has led to adoption of the term "sustainable transport systems".

There are Transport Management System (TMS) aids that ease the pressure on the planner, but these only partially

integrate the area of sustainable transport operations. TMSs are generic solutions mainly aimed at transport companies that deliver to regular customers. These solutions are unsuitable for integrating specific characteristics and for the diversity of customer demands, to which the transport company must respond, if it is not to lose the contract. Such solutions do not allow fleets of mixed vehicles to be managed (optimization of vehicle selection based on its energy autonomy and/or city/town center, suburban or regional customer locations). Driver allocation to delivery rounds is not systematically integrated into TMSs, although it is crucial to limit driver overtime and to equitably distribute workload among drivers. Ultimately, TMSs mostly ignore both health and safety aspects and consideration of different combined energies. Moreover, these aids are relatively expensive because they are usually divided into modules or systems; a purchase or subscription is required for each module, function or hardware item (the average cost of a rented module being 30 euros/month/truck and a module does not operate separately). Yet, cost is a major constraint, especially for VSEs/SMEs. All these curbs (unsuitability to customer diversity, to mixed fleets, no overtime management, cost of systems) oblige many VSEs/SMEs to perform their planning using a spreadsheet, a word processing program or even pencil and paper.

New proposals are required for planning sustainable transport services and these must take into account the financial, environmental and social issues.

Besides taking criteria into account for the quality evaluation of the generated tours, we would also propose solutions to integrate the measurement of the robustness of the solution to potential risks that could alter the planning done. In front of the complexity of its task, we should be able to suggest the planner some indicators to facilitating the selection and the choice of the best solution. Among these indicators, we propose to build a representative indicator of the confidence that can be attributed to a solution. By confidence we mean the ability of this solution to keep the commitments made, for

example with the customer or compliance with the maximum working time (time amplitude of the tour).

This article is divided into 5 parts. In section 2, we present a state of art for the selected issue. In section 3, the part of the methode to describe the work developed to address the problem. Section 4 contains an example to illustrate the proposals made. To finish, the conclusion takes stock of the situation and provides some ideas for complete this work.

II. STATE OF THE ART

A. Related work about risk analysis

For several years, we have led, in our laboratory, research dealing with the theme of analysis and control of risks in the project and process management. These works led to the development of innovative proposals based on the R-IO model [1, 2, 3]. These works aim to take into account all combinations of occurrence risks and their influence on schedules. Scenarios of schedules thus generated are evaluated according several criteria: probability of occurrence, duration, cost, and any other specific criteria for a type of evaluated schedule.

In the literature, risk management methods refer to a standard process with well-known steps: identification, assessment, quantification, treatment and risk monitoring [4]. [5] propose a classification with 62 existing approaches. Methods are sorted depending on whether they are deterministic and/or probabilistic, but also qualitative or quantitative. Gourc et al. offer a grid of different reading, classifying approaches of risk management whether they are symptomatic or analytical [6]. The first group of approaches, also called risk-uncertainty is associated with approaches where the project risk management is converted into managing uncertainty [7]. The second group of approaches views risk as an event that may affect the achievement of project objectives [8].

Two themes are well known for their reference to innovation and by the omnipresence of risk: (1) the project management of new product development (NPD) at an operational level. It consists of choosing an exclusive orientation as a development strategy. It considers a level of global tolerance of risk. (2) NPD portfolio management at a tactical level. A first definition of portfolio management is given by [9]: a dynamic of decision making that enables the list of projects to be always updated. In this process, new projects are evaluated, selected and sorted. Past projects can be accelerated, stopped, or paused and resource assignments can be modified in order to build a balanced portfolio of innovative projects, on a balance risk / profitability.

Representations of project plan and tour are very similar, all of them can be modelised with activity networks. So, we hypothesize that concepts and software tools developed on project risk management by our research team since a few years are totally relevant for assessment of the robustness of tour in transport sector.

B. Metric to assess the planning robustness

In the literature, the robustness notion is sometime used to talk about algorithm. But this review is based on the robustness of solutions.[10] point out that there is no unique definition of the term robustness. To qualify solutions, several authors propose definitions of robustness ([11, 12, 13]) define the robustness as the aptitude to which a system can function correctly in the presence of inputs different from those planned. [14, 15] describe that the concept of robustness should be defined for a given set of features and under a given set of possible disturbances. There is important to note that the Society for Risk Analysis recently proposed a definition of robustness[16]. A system is robust to perturbations when goals can be achieved despite disturbances occur.

In the context of transport planification, robust planning is defined as a planning that is insensitive to disturbances that might occur during the implementation of planned activities. The definition of a robustness metric aimed to measure the sensitivity/insensitivity of the planning to potential disturbances. The robustness can be assess using metrics. Those metrics must enable to reflect a-priori the planning's capacity of the tour to respect objectives or requirements that we define as the contractual space. Thus, in our context, the contractual space will be defined, for instance, by the tour's maximum working time, the maximum time for each driving period, etc.

The directed acyclic graphs can be used to model schedules and, by extension, tour transport's schedules. In the context of planning for directed graphs acyclic, [17] offer two definitions of the robustness and propose two expression of the robustness. The first is expressed by the multiplicative inverse of the expected value of relative schedule tardiness. The second is calculated by the multiplicative inverse of schedule miss rate.

This work addresses primarily deterministic graphs. For our problem, we are led to consider the probability of occurrence of hazards during the tour. These hazards can modify some characteristics of the graphs (duration of activities, modification of some links).

[18] and [19] propose a comparative analysis of several metric robustness. Metrics are:

- "makespan standard deviation"
- "makespan differential entropy"
- "slack mean"
- "probabilistic metric"
- "lateness likelihood"
- "makespan 0,99-quantile"

[20] and [21] also provide metrics taking the dynamic nature of environment into account for which schedules are generated. The robustness is expressed as the probability that the task performed, i.e. the tour, is finished in accordance with constraints, for instance the total duration or the delivery time.

III. PROPOSALS

Based on the results we obtained earlier, particularly in the ANR project PLAS'O'SOINS [22] related to the tour's planning of health workforce for the maintenance of patient

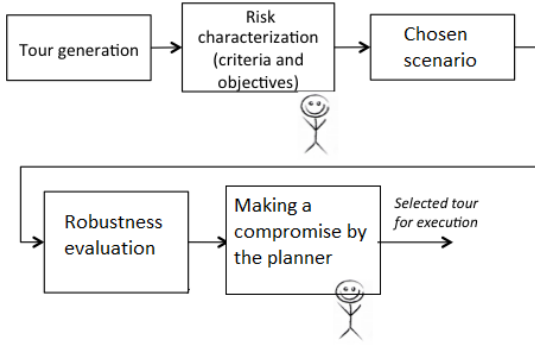


Figure 1. Proposed approach

at home [23] and our works on R-IO. The aim of the project PLAS'O'SOINS was to improve the actor's planification in health field with take in consideration risks . We propose to evaluate the quality of schedules generated by relying on the measure of possible scenarios induced by the possible occurrence of the identified hazards. For this purpose, we implement the ProRisk model on the schedule of activities concerning a tour.

A. Suggested approach

The proposed approach (Figure 1) consists of 5 steps. The first step consists in building schedules tours to serve the identified orders. Thus, on the basis of received orders, this step enables to produce a tour schedule set represented by process P described by their tasks $T_i, (i = 1...t)$. Based on the identified generic risks and planned activities in these processes, step 2 produces a list of specific risks for each tour and generates all the possible risk scenarios. In step 3 the planner choose plannings thus he wants to evaluate accord criteria selected. In step 4, the robustness are calculated to determine a other indicator, probability of commitments' respect, for each tour initially generated by step 1. Finally, step 5, conducted by the planner, aims to select the tour that best meets these requirements

B. Model proposal

A tour is presented as a process P composed by its tasks $T_i, (i = 1...t)$, where t is the number of tasks (Figure 2). A tour, mobilizing a vehicle and a driver, is a process involving a succession of activities alternating with:

- starting activity, corresponding at the begin of the tour with loading of the vehicle and preparing;
- driving activities, corresponding at all movumnt to connect two points, warehouses or on a delivery points;
- waiting activities, corresponding at the time to wait before delivery a site;
- activities on site (AoS), corresponding at loading and unloading goods on site and administratif part;
- closing activity, corresponding at the end of the tour with unloading goods and cleanning the vehicle.



Figure 2. example of process

A tour is considered feasible or acceptable if it meets a set of constraints C . The constraints can include for example the respect of a maximum duration of the tour, the respect of a time slot to a client, etc.

A tour is represented as a process P described by its tasks $T_t, (t = 1...T)$, where T is the number of tasks. The planning process provides a baseline P_i which does not include the risks. A set of critical resources (ERC) is required to process certain tasks. A process is also described by its set ER of identified risks $R_i, (i = 0...n)$, where n is the number of risks. Each R_i is characterized through the risk management process. A risk R_i is also characterized by its occurrence period, namely the tasks where the risk can occur. Its probability $proba(R_i)$ is the probability that the event related to R_i happens. Its impacts on costs are rated $CI(R_i)$ and the project duration $DI(R_i)$. The impacts may affect, by the domino effect, a different task from the one characterizing the period of occurrence. These probabilities and impacts are also named initial probability and initial impact. A risk scenario ScR corresponds to the combination of S risks occurring during a process P. A process with n risks leads to 2^n risk scenarios. $ScR_s, (s = 1, ..., 2^n)$ is one possible implementation with k risks $(0 \leq k \leq n)$. The total number of risk scenarios, presenting k risks is equal to $n!/k(n-k)!$. Its probability is noted $proba(ScR_s)$ (the probability that the events related to this risk scenario occur and other risks do not occur). Depending on type of tasks composing the process, certain generic risks can be identified, see Table I for an example.

A risk can have an impact on the strong constraints and thus make a scenario become not feasible but it also simply affect the indicators without modifying its feasibility.

Based on these hypothesis, we are implementing a ProRisk analysis process allowing to generate all possible scenarios and calculate the indicators characterizing each scenario. The aim is, first, to determine the probability of occurrence of risk scenario $proba(ScR_s)$. This probability of the scenario depends on the combination of risks in this scenario (Equation 1).

$$proba(ScR_s) = \prod_{i=1}^n \left\{ \begin{array}{ll} proba(R_i) & \text{if } R_i \in ScR_s \\ 1 - proba(R_i) & \text{if } R_i \notin ScR_s \end{array} \right\} \quad (1)$$

Beside the occurrence probability of a scenario, we characterize each scenario by other indicators. Very typically, the time and cost indicators are mobilized to effect this characterization. Thus, for each identified scenario, its duration and its cost are calculated. The expression of the cost calculation is shown in Equation 2. The project scenario cost is named $C(ScRs)$. It includes the cost of tasks $C(Tt)$ which constitute

Table I
EXAMPLES OF GENERIC RISKS DEPENDING ON THE TYPE OF TASKS

Task type	Example of generic risks	Possible cause(s)
Activity on site	Accident / injury of the driver	Missing operator in charge of handling Handling equipment not available Client is absent
	Mistake	Handling equipment not available
Driving	Accident / injury of the driver	Missing operator in charge of handling Handling equipment not available
	Driver vigilance drop	Loading/Unloading realized by the driver more important than estimated Long driving period
	Insufficient autonomy of the vehicle, especially for vehicles with green power electric only, gas only).	Extension of certain time (traffic jam, lowered performance of the energy source, e.g. battery)
	Accident / injury of the driver	Driver tiredness Technical problem
		Accident caused by a third

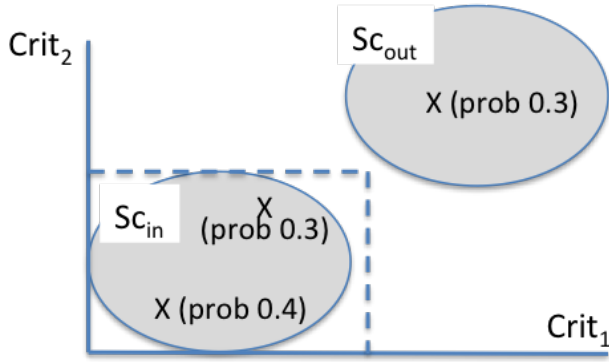


Figure 3. Illustration of Sc_{in} and Sc_{out} sets

the initial planning process, impacts of occurrence risks, i.e. risks present in ScR_s , on the process tasks and the global cost $GC^{initial}(R_i)$ of occurring risks. $GC^{initial}(R_i)$ is the aggregation of risk impacts on the cost criterium. This includes a fixed portion of the total cost (materials, tools, parts, etc.) and indirect costs depending on the duration of action of each possible impact of risk

$$C(ScR_s) = \sum_{t=1}^T C(T_t) + \sum_{R_i \in ScR_s} GC^{initial}(R_i) \quad (2)$$

C. Expression of the level of robustness

As a first approach, we propose to define a robustness indicator of each tour planning as the measure of the ability to respect contractual space expressed by the defined constraints. Thus, robustness $Ro(i)$ of the tour i , will represent the probability to respect this set of constraints Co . It is obtained from the occurrence probabilities of risk scenarios ScR_s , which respect constraints Co . This set of scenarios will be named Sc_{in} (Figure 3).

$$Ro(i) = \sum_{ScR_s \in Sc_{in}} proba(ScR_s) \quad (3)$$

At this stage, this expression represents a first formulation of a robustness indicator. We expect to offer a finer indicator to weight the importance of the scenarios that don't respect the constraints and maybe take in consideration indicators limits.

IV. NUMERICAL APPLICATION

A. Description of the example

For half a day planning, our partner may have to deliver three customers with one vehicle up to 200 customers with 20 vehicles. To illustrate our proposals, we consider an example situation in a low range of a real planning with 4 delivery points (Sit_j) and two couple vehicle, driver. We consider that vehicle are different the first one is an electrical vehicle and the second one is a diesel vehicle. These four delivery points are spread over a geographical area compatible with the vehicle's energy. The vehicle is stored in a warehouse (W_1), which also stores a portion of workpieces. Each point, warehouse and delivery point, can potentially be a place where loading and unloading's actions of the vehicle will be to achieve.

The list of orders to be processed is shown in the table (Table III). There are three orders starting at the warehouse and one where the picking point is the Sit_3 .

For each order are described:

- The place of loading of objects to transport (Origin);
- The place of unloading of objects to transport (Dest.);
- The loading time and unloading time calculated based on quantity;
- Time window where the driver can delivery goods.

Additional information can be mobilized, such as:

- Characteristics of the objects to be transported: volume in liter (Vol.), mass in kg, number of objects to be transported (Qty) per unit carton/ pallet.
- Presence of dock.

Two generic risks are considered, as described in Table II. The risk R_1 expresses the effects of the traffic jam when accessing to Sit_3 . The risk R_2 reported at a possible absence of the handler from his workplace if the delivery takes place between 10h00 am and 10h30 am. It is frequent, but not systematic, the handler in charge of loading / unloading the

Table II
LIST OF GENERIC RISKS

Risk	Description	Risk area	Concept type concerned / affected	Probability	Impact type
R_1	Traffic jam in urban area at rush hour	Access/departure Sit_3	Tour's task of type of ride	70%	Duration + 150 %
R_2	Handler unavailable	Loading/unloading to Sit_2 between 10h00 and 10h30	Tour's task of type of loading/unloading	80%	Duration + 20 mn Driver provides loading/unloading → additional driver fatigue
R_3	Bad indication to the location of the goods delivery on the Sit_1	Sit_1	Tour's task of type of loading/unloading	50%	Duration + 15min

truck, takes his break at that time. The risk R_3 expresses the possibility that a driver does not know the localisation where goods need to be delivery just for the Sit_1 .

In a complementary manner, the constraints of the transport company, inherited from legal and regulatory constraints require that:

- Time allowed for a tour does not exceed 5h;
- Driving periods shall not exceed not 1h;
- The autonomy of electrical vehicle is 4h.

B. Results and discussion

To comply with the orders to be processed and any eventual constraints, for example it's an obligation to go at the delivery point Sit_3 before the delivery point Pli_4 , there are 40 solutions for the tour. A part of this 40 solutions are shown in Table IV. This table shows the succession of points to visit, starting from the warehouse W_1 and go back to the warehouse W_1 .

The initial schedule proposed for the solution S_1 is shown in Figure 4, it shows the details of the solution S_1 , indicating for each activity required:

- Its type: start, driving loading, unloading, ending of the tour when come back at the warehouse;
- Duration of each activity ;
- The activity's start time.

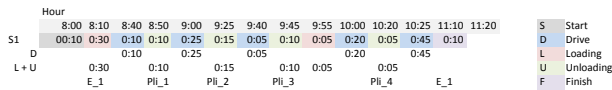


Figure 4. Example of planning for the solution S1

This solution can be characterized by many criteria:

- Time allowed;

Table III
LIST OF ORDERS

Order	Origin	Dest.	Loading time	Unloading time	Time window
O_1	W_1	Sit_1	-	00h10	[8h-13h]
O_2	W_1	Sit_2	-	00h15	[8h-11h]
O_3	W_1	Sit_3	-	00h10	[8h-13h]
O_4	Sit_3	Sit_4	00h05	00h05	[10h-13h]

Table IV
SOLUTIONS TO REALIZE DELIVERY ORDERS

Solution	V_1	W_1	Sit_1	Sit_2	Sit_3	Sit_4	W_1
S_1	V_1	W_1	Sit_1	Sit_2	Sit_3	Sit_4	W_1
S_{20}	V_1	W_1	Sit_1	Sit_2	Sit_3	Sit_4	W_1
S_{21}	V_1	W_1	Sit_1	Sit_2	Sit_3	Sit_4	W_1
S_{40}	V_1	W_1	Sit_1	Sit_2	Sit_3	Sit_4	W_1

- The maximum driving time;
- Total driving time;
- Autonomy of the vehicle V_1 ;
- Total time for loading and unloading;
- Environmental impact of the solution.

In the example discussed in this article, only some of these criteria are implemented and associated values are take in consideration.

From these results, the solutions do not respect the constraints set forth above may be dismissed: respect of the maximum amplitude of 4 hours, etc...

For the second step of the proposal three risks are created. Eight risk scenarios may occur:

- None risk: ScR
- Only the risk R_1 occurs: ScR_{R_1} ;
- Only the risk R_2 occurs: ScR_{R_2} ;
- Only the risk R_3 occurs: ScR_{R_3} ;
- Risks R_1 and R_2 occur on the same tour: ScR_{R_1,R_2} ;
- Risks R_1 and R_3 occur on the same tour: ScR_{R_1,R_3} ;
- Risks R_2 and R_3 occur on the same tour: ScR_{R_2,R_3} ;
- Risks R_1 and R_2 and R_3 occur on the same tour: ScR_{R_1,R_2,R_3} .

Each senario have a probability of occurence describe in the (Table VI). This probability is calcul with different value of all potencil risk.

To simplify indicators calcul we propose in first time to considere that the time allowed is the cost, the driving time by the vehicle V_2 is the environmental impact and the driving time is the indicator of health and sécurité. On these first results,

Table V
INFLUENCE OF RISKS ON GENERATED SOLUTIONS

	ScR :	ScR : R ₁	ScR : R ₂	ScR : R ₃	ScR : R ₁ ; R ₂	ScR : R ₁ ; R ₃	ScR : R ₂ ; R ₃	ScR : R ₁ ; R ₂ ; R ₃
Solution	Validity	Validity	Validity	Validity	Validity	Validity	Validity	Validity
S ₂	Yes	No	Yes	Yes	No	No	No	No
S ₁₈	Yes	No	Yes	Yes	No	No	Yes	No
S ₄₀	Yes	Yes	Yes	Yes	Yes	No	Yes	No

Table VI
SCENARIO PROBABILITY

Scenario	Occurence (%)
ScR :	3
ScR : R ₁	7
ScR : R ₂	12
ScR : R ₃	3
ScR : R ₁ ; R ₂	28
ScR : R ₁ ; R ₃	7
ScR : R ₂ ; R ₃	12
ScR : R ₁ ; R ₂ ; R ₃	28

Table VII
SOLUTIONS CHOSE BY THE PLANNER

Solution							
S ₂	V ₁	W ₁	Sit ₁	Sit ₃	Sit ₄	Sit ₂	W ₁
	V ₂	-	-	-	-	-	-
S ₁₈	V ₁	W ₁	Sit ₃	Sit ₄	Sit ₂	W ₁	-
	V ₂	W ₁	Sit ₁	W ₁	-	-	-
S ₄₀	V ₁	W ₁	Sit ₃	Sit ₄	W ₁	-	-
	V ₂	W ₁	Sit ₁	Sit ₂	W ₁	-	-

the planner have a lot of indicator to select few scenario as presented in the (Figure 1) step 3. To illustrate the robustness we chose three solutions S₂, S₁₈ and S₄₀ (Table VII). S₂ is at first glance a good solution on the environmental indicator because the planning is realized also by a electrical vehicle. S₄₀ is better than the solution S₂ on the health and security indicator because the repartition of the delivery is balanced. S₁₈ is maybe chose for find a compromise between all solution.

Table V shows for each scenario, the same verification of the compliance constraints can thus be performed, as shown by the columns “validity”.

Table VIII
SENSIBILITY OF SOLUTIONS TO DISTURBANCES

Solution	Robustness	Preferred solution
S ₂	0.18	
S ₁₈	0.3	
S ₄₀	0.65	X

Finally, the aggregated criteria of measure of the probability to respect constraints is calculated as shown in Table VIII. The solution S₂, previously identified as the best solution on the environmental level to be highly sensitive to disturbances: 82% of chance to not respect the constraints often the constraint doesn't respected was the autonomy of the vehicle but the time allowed at the tour is also exceeded. For solutions S₁₈ and S₄₀ they are not valide on few senario only cause by

the autonomy of vehicle. The same solution with vehicle V₁ and V₂ swap will be a robust solution.

The robustness is an other indicator to help the planner to chose an appropriated solution. It's not because a solution is considerate less robust than an other that it is not possible to chose it. The Planner need to realize a lot of compromise and the robustness has to aim to help him in this chose. The robustness shows the solution unstable but this shows also that the first vision of indicator can be unstable and this view should be change the chose of the planner.

V. CONCLUSION

In the planning process, planners are generally facing with lack of indicators that are used to detremine the influnece of the risk on choosing the solution. In addition in these problems, there is a complexity which originates from the impact of risks on the genration of the solutions while trying to satisfy constraints and modify indicators of the first solution. In this study, we proposed a model and a generic approach to help the planners with better evaluation and comparasion of the obtained oriented solutions. For this purpose, we propose a set of indicators that are used to characterize each of the solutions. In a complementary manner, and to reflect the dynamic and stochastic character of execution environment of tours, we present an indicator that determines the robustness of the solutions. This indicator expresses the ability of the solution to respect the framework of constraints despite potential disruptions. We plan to continue the definition of indicators by adding precision, particularly using different ways of weighting the various solutions outside of framework. For example, a solution that does not respect one of the identified constraints will have a different weight of another solution by not observing none constraints.

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