A generic heuristic for multi-project scheduling problems with global and local resource constraints (RCMPSP)

Abstract. This paper presents a novel algorithm to solve the multi-project scheduling problem with resource constraints (RCMPSP). The algorithm was tested with all the problems proposed in the Multi-Project Scheduling Problem Library (MPSPLib), which is the main reference to benchmark RCMPSP algorithms. Our analysis of the results demonstrates that this algorithm, in spite of its simplicity, outperforms other algorithms published in the library in 16% of the cases and holds the best result in 27% of the cases. These results, along with the fact that this is a general-purpose algorithm, makes it a good choice to deal with limited time and resources in Portfolio Management.

Keywords. Project Management, Project Scheduling, Portfolio Management, Multi-project Scheduling, RCMPSP, MPSPLib.

1 Introduction

Project Scheduling involves finding a start and finish time for all the project activities, considering a set of limitations such as precedence relations, temporary restrictions and resource constraints, while a predefined scheduling objective is optimized.

The real impulse for Project Scheduling took place with the emergence of scheduling methods based on Graph Theory in the late 1950s, such as PERT (Program Evaluation and Review Technique) (Malcolm et al. 1959), CPM (Critical Path Method) (Kelley and Walker 1959) or ROY (Algan et al. 1962). All of these methods allowed calculating the project duration and the start and finish times of the activities in a mechanical and relatively easy way.

However, these methods assumed that all the resources required by the activities would be available at the time of their execution. This assumption is unrealistic in practice because resources are normally shared between several activities in the project. Whenever two or more activities need the same resource at the same time, it needs to be determined what activities get the resource (and can be executed at the scheduled moment), and what activities need to be re-scheduled (i.e. be delayed, be interrupted or be executed more slowly). This decision has to be made repeatedly during all the scheduling process. Consequently, these constraints often lead to a complex scheduling problem that does not guarantee finding the optimal schedule for a project. (Villafañez et al. 2014a).

Later in time, several linear techniques started to be applied in order to try to solve this scheduling problem (Patterson 1973, 1984; Demeulemeester and Herroelen 2002). Over the years, this problem began to be called Resource-Constrained Project Scheduling Problem (RCPSP) and it became a field of research in the Project Management's literature (Hartmann and Briskorn 2010).

However, if we focus on real-life scheduling situations, companies do not normally handle a single project but a set of projects (Villafañez et al. 2014b). This multi-project case obviously increases the difficulty of the scheduling process due to the possible existence of resources that need to be shared between several projects (e.g. facilities, machines, human resources, etc.). The study of this issue was given the name RCMPSP (Resource-Constrained Multi-Project Scheduling Problem) (Fendley 1968; Davis 1969).

In this paper, we present the algorithm P-SGS/MIN-SLK[1] for the resolution of the RCMPSP (multi-project case). It is an adaptation of a method proposed by Kolisch (1996a; 1996b) that was used to solve the RCPSP (mono-project case) (Kolisch and Hartmann 1999; Hartmann and Kolisch 2000). We also present the results obtained after its application to solve all of the scheduling problems collected in a well-known repository of RCMPSP problems: the library MPSPLib[2] (Homberger 2007). After testing the algorithm with all of the 140 problems proposed in MPSPLib, we found that it provides better results than many other solutions published in the library. This is in spite of the fact that P-SGS/MIN-SLK is a general-purpose algorithm whereas other algorithms whose solutions were published in the library were built ad-hoc (i.e. they were specifically adapted to solve a particular scheduling problem). Our achieved solutions for these problems have been uploaded to the library and can be found under the name PSGSMINSLK[3].

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[1] Parallel Schedule Generation Scheme (P-SGS) and minimum activity total slack (MIN-SLK) as a priority rule

[2] www.mpsplib.com

[3] http://www.mpsplib.com/ranking.php?method=&criterion=tms&j=&p=&g=

The rest of the manuscript is organized as follows: in Section 2 we briefly review some techniques for Project Scheduling in order to provide a framework for the algorithm that we present in this paper. Section 3 describes the heuristic P-SGS/MIN-SLK that we have implemented. Then, in Section 4 we present an example of the application of this algorithm in a simplified multi-project case. In section 5, we show the results of the application of the algorithm to all of the instances proposed in the library MPSPLib and we prove that, in spite of its simplicity, it outperforms many other algorithms designed to solve particular problems ad-hoc. Finally, in section 6, we present the conclusions of this work and discuss about some questions for future research.

2 Background on Project Scheduling: some approaches to solve RCPSP (mono-project) and RCMPSP (multi-project)

A feasible scheduling requires finding a proper combination of resources for the activities within the project (mono-project case, RCPSP) or within the projects (multi-project case, RCMPSP) in such a way that certain resource capacities and time constraints are met.

Nevertheless, finding the optimal solution by means of the classical methods proposed by Operational Research is not feasible even with the most recent computer systems. In fact, both RCPSP and RCMPSP are considered in terms of Complexity Theory as NP-Hard problems in strong sense (Blazewicz et al. 1983). This means that, whenever a feasible solution is found, it is not possible to know if this solution is optimal in the case of complex problems (Bartusch et al. 1988; Schirmer 1996).

Both RCPSP and RCMPSP can be conceptually modelled as a linear problem (Pritsker et al. 1969; Alvarez-Valdés Olaguíbel and Tamarit Goerlich 1993; Kaplan 1996; Mingozzi et al. 1998; Klein 2000). However, due to the difficulties in finding the optimal solution for the RCMPSP with this formulation, the scientific community has recently explored alternative ways of tackling this issue. These methodologies include heuristics and metaheuristics, such as ant colony optimization algorithms (Fink and Homberger 2013), simulated annealing (Dalfard and Ranjbar 2012), combinatorial auctions (Araúzo Araúzo et al. 2010; Villafáñez and Poza 2010; Song et al. 2016), genetic algorithms (Pérez et al. 2015) or multi-agent systems (Zheng et al. 2014). More recently, statistical learning techniques have proved to be promising in the field of Project Scheduling (Acebes et al. 2015; Wauters and Vanhoucke 2017), and also in other fields (Semwal et al. 2015, 2016, 2017).

These resolution methods are usually organized into two categories, namely **centralized approaches** (C-RCMPSP) and **decentralized approaches** (D-RCMPSP) (Villafañez et al. 2014b).

The centralized approach was introduced by Pritsker, Watters, et al. (1969) and Kurtulus & Davis (1982). According to this approach, a unique decision-maker decides the scheduling for all the projects (Blazewicz et al. 1983; Kolisch et al. 1995; Kolisch and Sprecher 1996; Kolisch 1996b; Brucker et al. 1999). Therefore, the centralized methods work well for the optimization of global objectives in the set of projects, such as the minimization of the total makespan (TMS) (Kurtulus and Davis 1982; Özdamar and Ulusoy 1995). In practice, the C-RCMPSP tackles the RCMPSP as an equivalent mega-project with a single critical path that can be solved as an RCPSP (see Figure 1).

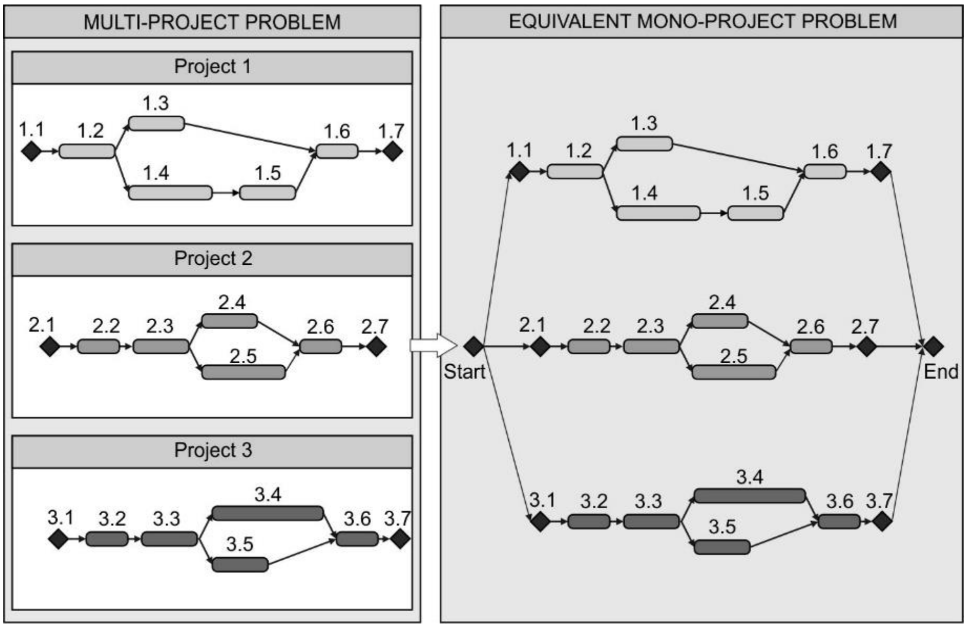

Figure 1. Conceptual description of the centralized approach for the RCMPSP (C-RCMPSP)

The D-RCMPSP, however, considers several independent decision entities: one for each project and another for the portfolio (Confessore et al. 2002, 2007; Fink and Homberger 2015) (see Figure 2).

This approach does not only allow applying a global optimization criterion for the portfolio (as in the C-RCMPSP case), but it also allows each project to maintain certain control over its own critical path in the scheduling process, while trying to optimize its schedule based on different possible project performance measures.

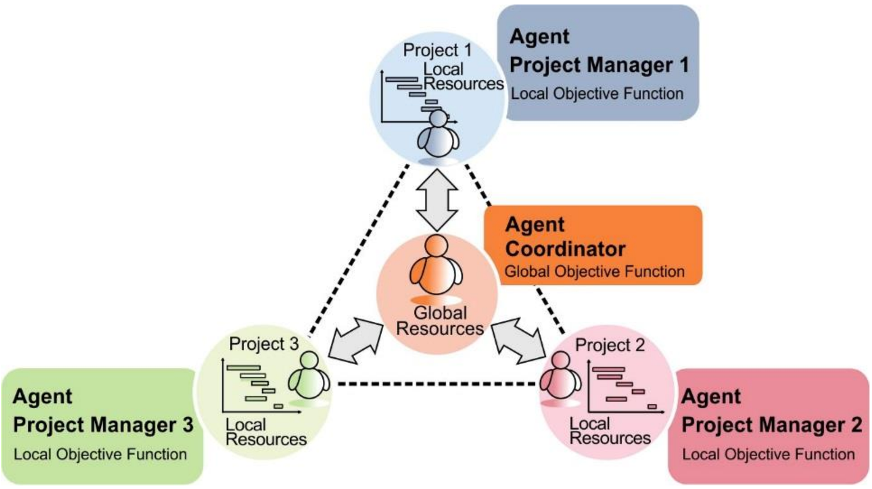

Figure 2. Conceptual description of the decentralized approach for the RCMPSP (D-RCMPSP)

Focusing on the centralized methods, the priority rule-based approach for solving the mono-project case (Kelley 1963; Kolisch 1996b) is the most widely used technique to solve the multi-project case due to its simplicity (Herroelen 2005). This heuristic uses two components in order to build feasible project schedules that respect the resource constrains, namely: a Priority Rule (PR), which is the criterion (or criteria) used to determine the order in which the set of project activities whose predecessors have been completed (i.e. candidate activities) will be tried to be scheduled, and a Schedule Generation Scheme (SGS), which is the particular procedure used to obtain the list of candidate activities.

On the one hand, the most well—known generation schemes are (Boctor 1990):

- *Serial Schedule Generation Scheme (S-SGS):* an algorithm determines the order in which the activities will be tried to be scheduled only once at the beginning of the scheduling process.
- *Parallel Schedule Generation Scheme (P-SGS):* the algorithm dynamically re-determines the activities that can be scheduled at every scheduling period On the other hand, the **priority**

rule determines the order in which the activities whose predecessors have been completed will be tried to be scheduled. There exist a wide range of priority rules (Lova and Tormos 2001; Lova et al. 2006). They are usually based on one or more of these sources of information: activities information (e.g. their processing times or cost estimates), resources information (e.g. information about the resources constraints), network information (e.g. the number of immediate or total successors) scheduling information (e.g. the activities' earliest start time, latest finish time, free slack or total slack).

3 Implementation of the algorithm P-SGS/MIN-SLK

Following Rainer Kolisch (1996), our algorithm to solve the RCMPSP is a **centralized method**, which is based, as discussed in Section 2, on two components: a scheduling generation scheme and a priority rule. Concretely, the algorithm uses a **parallel schedule generation scheme** (P-SGS) and the **minimum total slack** (MIN-SLK) as a priority rule. The combination of these terms gives name to the heuristic that we have implemented to solve the RCMPSP: **P-SGS/MIN-SLK**.

Figure 3 shows a flow diagram of our implementation of the heuristic. The basic idea of the algorithm is the following: first, we create a preliminary schedule following the Critical Path Method (CPM): this implies that the resource constraints are ignored (i.e. the activities are scheduled as if the number of resources and their capacity were infinite). This leads to a tentative schedule that cannot be implemented because the resources required by the activities may not be available at the times they are requested. However, it will be the basis of the scheduling process.

Then, following the guidelines of a parallel scheduling generating scheme, at every time step we create a list with all the activities that can potentially be scheduled at the current time. This list contains activities from several projects whose predecessors have already been completed. We will call these activities 'candidate activities'.

The next step is to determine the order in which the candidate activities will be tried to be scheduled. The criterion used to sort this list (i.e. the priority rule) is the minimum total slack. This means that the candidate activities will be prioritized from the shortest to the longest total slack.

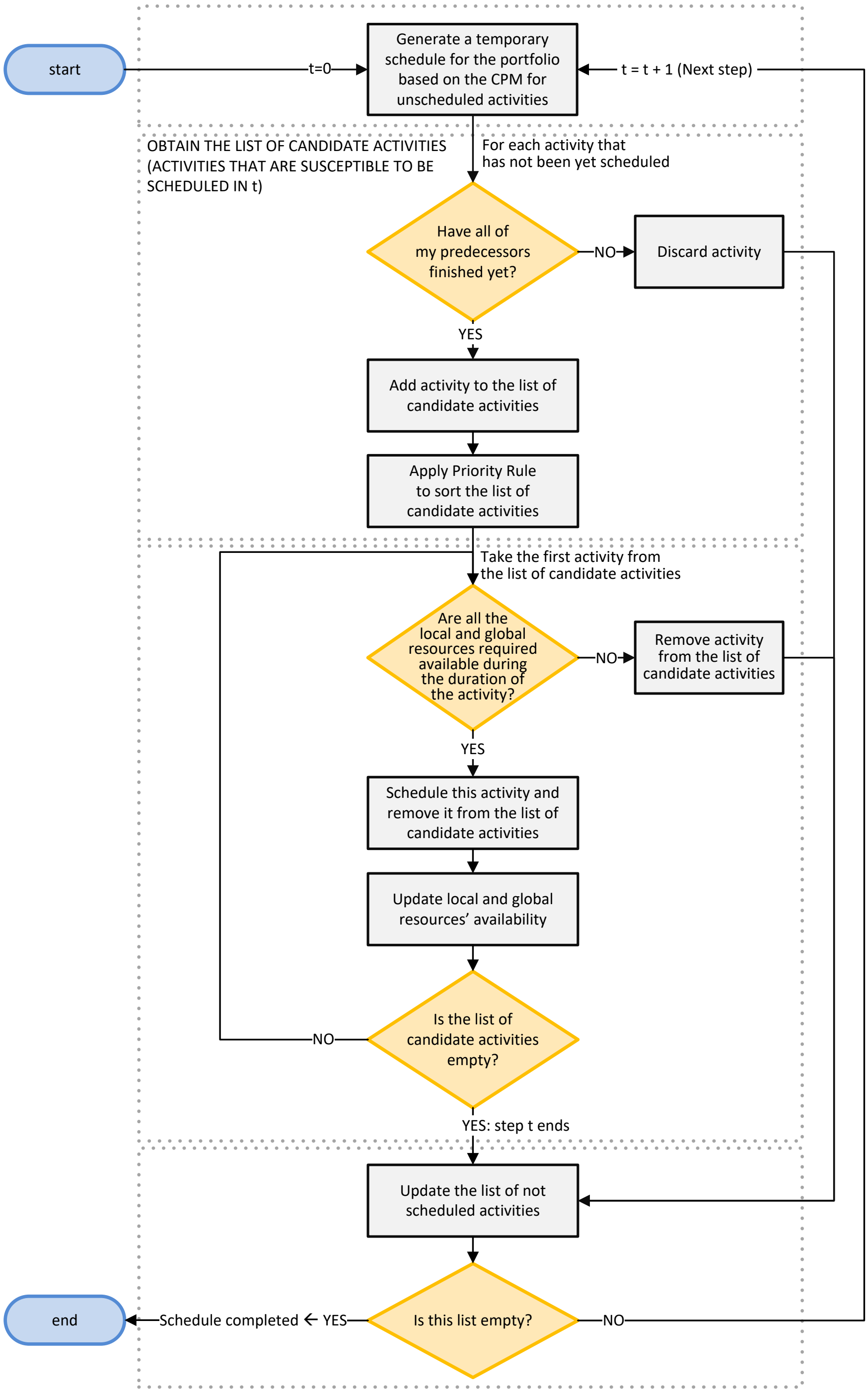

Figure 3. Flow diagram of the implementation of the P-SGS/MIN-SLK heuristic

Once we obtain the prioritized list of candidate activities, we try to schedule them one by one, starting from the first activity in the list (i.e. the one with the shortest total slack). In order to ensure the non-violation of the resource constraints, we check if the resources needed by that activity are available during the entire duration of that activity (notice that we assume that the activities cannot be interrupted during its execution). Depending on the availability of resources, two things can happen: if there are enough resources available, then the activity is scheduled and the resources' availability for the next periods is updated (i.e. the previous resource's availability minus the amount of resource consumed by the activity that has just been scheduled during its whole execution). However, if the amount of resources is not enough, that activity will be delayed one time slot, when the resource constraints might meet. In any case, the activity is removed from the list of candidate activities.

Afterwards, we will proceed in the same way with the next candidate activity in the list and so forth. The current scheduling step finishes when the list of candidate activities is empty.

We will proceed likewise in the successive scheduling steps until all the activities have been scheduled. The tentative scheduled obtained at the beginning of each time step will contain two types of activities: activities that have already been scheduled in previous time steps (whose scheduling is definitive); and activities that are yet to be scheduled (which will be tentatively scheduled with the CPM method, and that are still subject to delays if the resources they need are not available).

As long as the priority rule is concerned, it is important to mention that ties are possible since two or more activities might have the same total slack. In order to break these ties, we use a secondary prioritization rule: random selection, which means that ties are broken randomly. The randomness introduced by this secondary priority rule provokes that different runs of the algorithm may yield different feasible solutions for the same problem. Consequently, we can apply the algorithm repeatedly and then retain the best solution for each iteration. As a result, the larger the number of executions of the algorithm, the higher the likelihood of finding the optimal solution.

4 Multi-project scheduling with P-SGS/MIN-SLK

For illustrative purposes, let us consider a simplified case with only three projects and two resources. For a better interpretation of the scheduling process, we will assume that these three projects form a project portfolio for a company. We will also consider that both resources are shared between all the three projects (i.e. global resources) for the sake of simplicity. However, P-SGS/MIN-SLK supports both local and global resources as stated before. The precedence relationships of the three projects are shown in (Figure 1, left). Recall that the heuristic P-SGS/MIN-SLK is a centralized method and thus it handles the set of projects as a virtual 'mega-project' composed of the activities of all its comprising projects (Figure 1, right).

- **Initialization (t = 0)**

The top of Figure 4 shows the schedule obtained with the Critical Path Method (CPM). Recall that in this tentative schedule, the resource consumption is ignored. Following this criterion, the Critical Path Duration (CPD) for projects 1, 2 and 3 are respectively 22, 21 and 18 time units. In order to illustrate the functioning of the algorithm, let us assume that the three projects start in different dates: project 1 will start in time-slot 0, whereas projects 2 and 3 will start in time-slots 1 and 5, respectively.

The duration of the whole portfolio (i.e. TMS, Total MakeSpan) is calculated as the difference between the finish date of the last activity of the portfolio and the start date of the first activity of the portfolio, which is 23 time units in this example, as Figure 4 shows.

The bottom of Figure 4 shows the number of resource units required at every time step for the implementation of this initial schedule. In this simplified example, we have two resources whose maximum capacity is 7 and 5 units per time-slot respectively. Notice that these two resources are shared by the three projects in the portfolio (i.e. they are 'global resources' according to the RCMPSP's nomenclature). The amount of resources (1 and 2) required is shown in brackets next to each activity. As shown in Figure 4, the CPM scheduling for this portfolio exceeds the maximum capacity of both resources at several time-slots: the maximum capacity of resource 1 is exceeded in time-steps 4 to 15 and the maximum capacity of resource 2 is exceeded in time-steps 5 to 8. This implies that this temporary schedule is not viable.

We create the list of candidate activities (i.e. activities that potentially can start at the current time-slot because either they have no predecessors or all of their predecessors have already been scheduled). In this case (Figure 4), there is only one candidate activity: *activity 1.2* (i.e. project 1, activity 2). Since there is only one candidate activity, the prioritization algorithm obviously determines that this is the next activity to schedule.

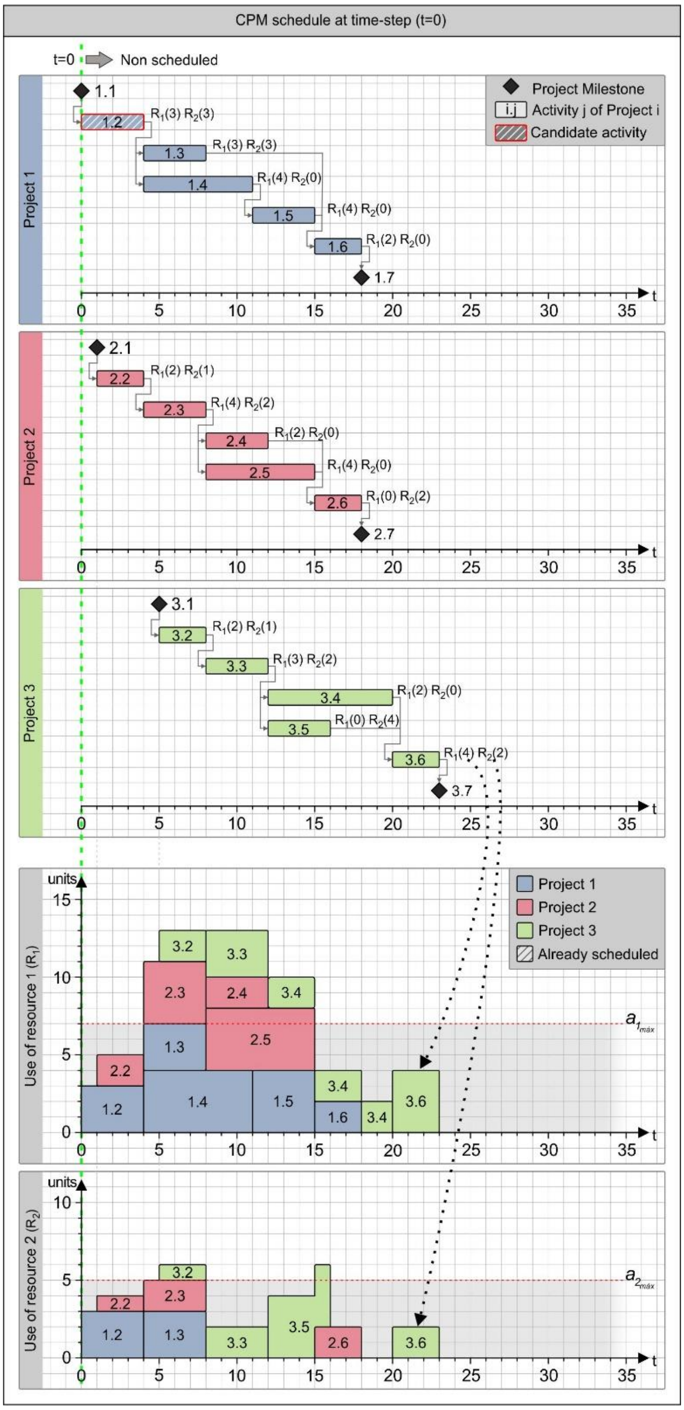

Figure 1. Initial (CPM) scheduling and demand of resources at time-slot t = 0

Afterwards, the algorithm checks if all the resources needed by this activity are available during its whole duration (i.e. 3 units of resource 1 plus 3 units of resource 2, both during 4 time-slots). Since no activities have yet been scheduled, the current availability of resources equals the resource's maximum capacity (7 units for resource 1 and 5 units for resource 2). Since all the resources are available during the whole duration of the activity, it is definitely scheduled between time-slots 1 and 4.

The current availability of resources is now updated by subtracting the amount of resources consumed by the activity that has just been scheduled from the amount of resources available before that activity was scheduled. In this case, the scheduling of the activity 1.2 modifies the availability of resources 1 and 2 during the next four time-steps, as Figure 5 shows. Since there are no more candidate activities, the first step of the scheduling process ends at this point. Should there be more candidate activities in the current step, the algorithm would try to schedule them following the order in the list of candidate activities, taking into account the changes in the availability of resources as the activities are scheduled.

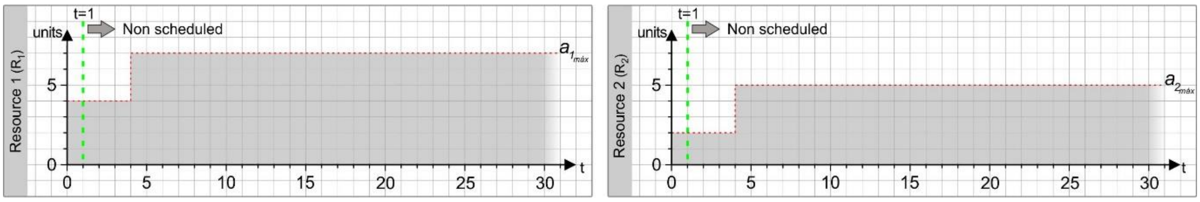

Figure 5. Resource availability after time-step t = 1

- **An intermediate time-step: t = 15**

A temporary schedule is generated at the beginning every intermediary step. This temporary schedule is composed of two types of activities: on the one hand, the activities that could be scheduled in previous steps (whose schedule is final) and, on the other hand, a set of activities that are yet to be scheduled, which will be temporarily scheduled according to the CPM and are subject to be delayed during the rest of the scheduling process.

At this point, the activities 1.2, 1.3, 1.4 (project 1), 2.2, 2.3 (project 2), 3.2, 3.3 (project 3) have already been scheduled in previous time-steps. These activities are shown dashed in the top of Figure 6. Notice that the algorithm guarantees that the activities that have been scheduled so far do not violate the maximum capacity of any of the resources. The scheduling for these activities is definitive.

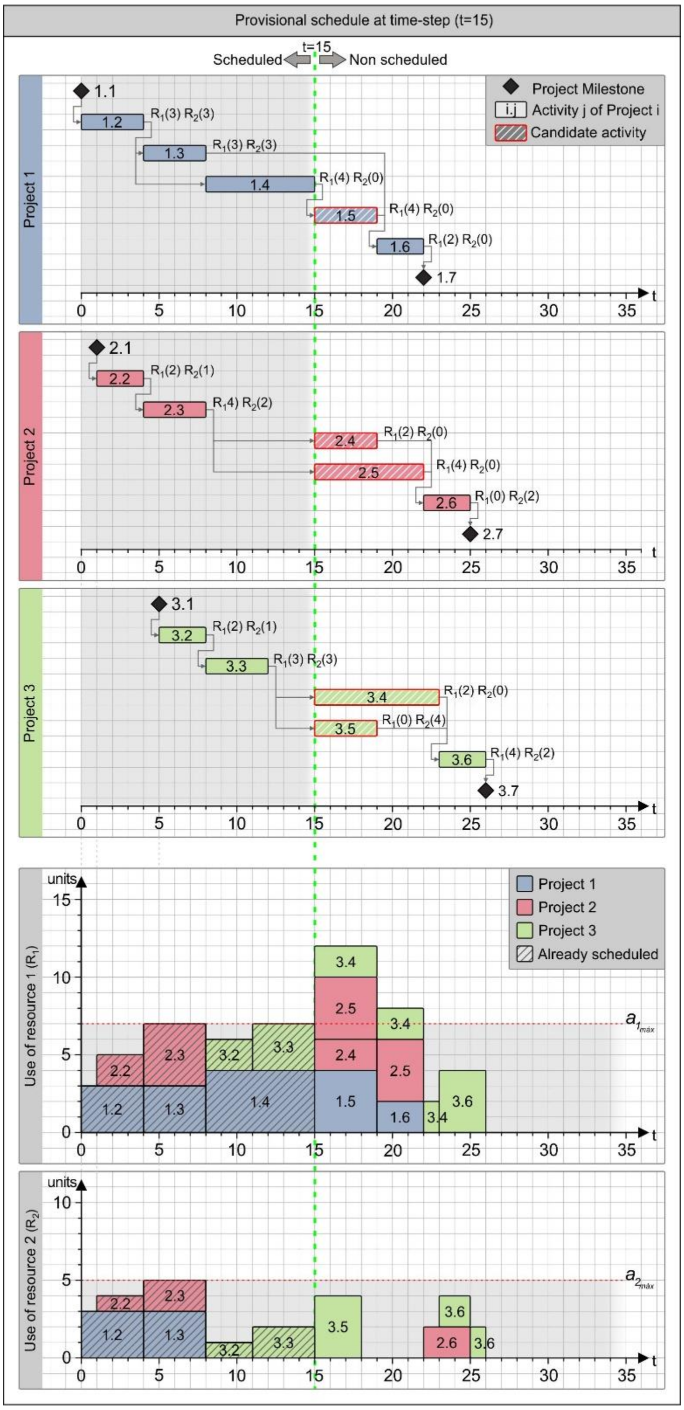

Figure 6. Scheduling process at time-step t = 15

The rest of the activities (1.5, 1.6, 2.4, 2.5, 2.6, 3.4, 3.5 and 3.6), which have not been scheduled in previous time-steps, are tentatively scheduled according to the CPM (see Figure 6), which means that its schedule is subject to change in the current or in later time steps. If we compare this tentative schedule with the one created in time-step 0 (Figure 5), it is to remark that the activities 2.4 and 2.5 could not be scheduled to start at t=8 as it was initially planned because at that time the resources needed by these activities were allocated to other activities (see bottom of Figure 6). Consequently, during time-steps 8 to 16 these two activities were delayed, once at a time-step.

There are five candidate activities at the current time-step as Figure 6 shows: 1.5, 2.4, 2.5, 3.4 and 3.5. The priority rule prioritizes the candidate activities from the shortest to the longest total slack, which determines the order in which these activities will be tried to be scheduled: 3.4, 2.5, 1.5 2.4 and 3.5. Notice that the activities 3.4, 2.5 and 1.5 have the same total slack, but this tie is solved randomly. Following this order, the activity 3.4 is successfully scheduled.

The bottom of Figure 6 shows the use of resources during the scheduling process. After subtracting the resources consumed by that activity, there are still enough resources to schedule the activity 2.5, which is successfully scheduled. However, the activity 1.5 cannot be scheduled at this time-step because there are not enough resources remaining (there is only one unit of resource 1 available during time-steps 15 to 22 whereas this activity requires four units of this resource). A similar situation occurs with activity 2.4, which cannot be scheduled due to lack of resources. The activity 3.5, however, is successfully scheduled since the four units of resource 2 it requires are available during its whole duration.

Notice that the candidate activities that could not be scheduled in the current iteration will be delayed one time-slot in the next iteration provisional scheduling (and so will all of their successors).

- **Final schedule: time-step t = 30**

After a number of steps, the algorithm provides a feasible schedule in which all the resource constraints are met (Figure 7). At this point, the dummy activities 2.7 and 3.7 are scheduled. Since there are no more pending activities, the scheduling process ends at this point, yielding a total make-span (i.e. duration of the whole portfolio) of 30 time units.

Notice that the activities 1.5 and 2.4, which could not be scheduled in time-step 16, become candidate activities during time-steps 17 to 22, but they could not be scheduled due to lack of resources. Consequently, they were successively delayed one time-unit. This situation persisted until time-step 22 and time step 23, in which the activities 1.5 and 2.4 were scheduled, respectively.

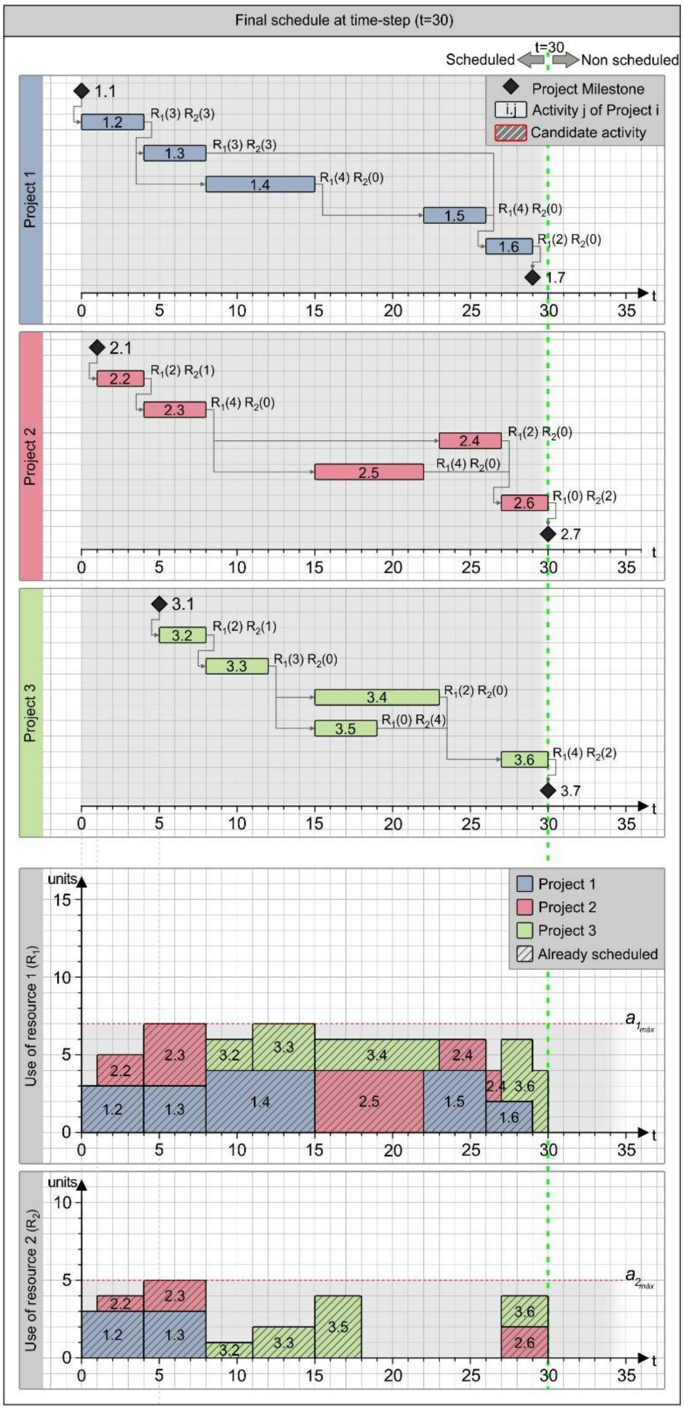

Figure 7. Final schedule at time-step t = 30

5 MPSPLib as a benchmark for P-SGS/MIN-SLK

In order to test the performance of the heuristic P-SGS/MIN-SLK, we made full use of MPSPLib, which is currently the most accepted collection of multi-project problems to test, evaluate, and compare different RCMPSP algorithms proposed by the scientific community (Wauters et al. 2015). MPSPLib[4] (Multi-Project Scheduling Problem Library) is a well-known public library that contains a collection of 140 artificial multi-project problems. It was initially proposed by Jörg Homberger in order to test a decentralized RCMPSP based on a multi-agent system (Homberger 2007). Each of these 140 multi-project problems is a combination of several mono-project problems that had been previously collected in the library PSPLib[5] (Library for Project Scheduling Problems) by Rainer Kolisch & Sprecher (1996). Although MPSPLib was initially conceived to test the decentralized multi-project problem, DRCMPSP, it is thoroughly valid for the centralized problem, CRCMPSP (Wauters et al. 2015).

Each problem is a combination of several projects with similar features in terms of number of activities. However, they are very different when it comes to the intensity of use of the resources shared by the activities. The library considers two types of resources: local resources (they can be used exclusively by the activities of one of the projects) and global resources (they can be shared between activities of different projects). MPSPLIB is, to our knowledge, the only public library that considers the complexity introduced by the consideration of both local and global resources in the same problem. Although the number of global resources varies from one problem to another, there is always at least one global resource (notice that if all the resources were local, that would not be considered as a RCMPSP, but simply a combination of several RCPSP). Either global or local, all the resources are considered renewable, i.e. the total capacity of each resource has a constant value per time slot during the whole time horizon.

This library does not only propose a collection of multi-project problems to test RCMPSP heuristics but it also offers researchers the possibility of uploading the results obtained with their algorithms. It

[4] http://www.mpsplib.com
[5] http://www.om-db.wi.tum.de/psplib/library.html

should be taken into account, however, that testing an algorithm with a library of instances is just one part of the process of evaluation (Barr et al. 1995) since it also depends on the hardware equipment and the quality of the code used for its implementation. Always bearing this in mind, MPSPLib considers three measures as an indicator of the quality of the scheduling obtained with an algorithm:

- *Total Makespan (TMS):* it is the duration of the whole set of projects, measured as the time elapsed between the beginning date of the first activity and the ending date of the last activity in the set of projects.
- *Average Project Delay (APD):* For a single project, the project delay (PD) is the difference between the critical path duration of the project (which ignores the resources constraints) and the duration of the final schedule (which meets these constraints). For a set of projects, the APD is the arithmetic mean of the PD of the projects comprising it.
- *Standard Deviation of Project Delay (DPD):* Similar to APD, but considering the standard deviation instead of the arithmetic mean.

The problems collected in MPSPLib are artificial. However, from a more realistic point of view, the set of projects comprising each RCMPSP could be considered as the portfolio of projects run by a company. In this case, it is reasonable to consider that, among these three indicators, the most useful for a generic company would be the total makespan (TMS). A company would probably wish to minimize the execution time of its whole portfolio (TMS) rather than trying to obtain a similar delay in all the projects comprising the portfolio (APD or DPD). This reason led us to use the total makespan as an indicator of the performance of P-SGS/MIN-SLK.

After applying the heuristic P-SGS/MIN-SLK to solve all of the 140 datasets, we uploaded the results into MPSPLib (a summary of this information can be found in the Appendix to this article[6]). Each row in the table compares the resulting total duration of the set of projects (total makespan, TMS) provided by our implementation (under the name of PSGSMINSLK) and the best solution achieved

[6] The results can be found under the name of PSGSMINSLK at MPSPLib: http://www.mpsplib.com/ranking.php?method=&criterion=tms&j=&p=&g=

by other algorithms. We observe that the results provided by P-SGS/MIN-SLK are at least as good as other solutions in 38 / 140 problems, that is to say, over 27% of the datasets.

As seen before, P-SGS/MIN-SLK is based on a priority rule. It should be taken into account that the performance of a particular priority rule depends on the concrete problem where it is applied and vice versa, the same algorithm with a different priority rule may lead to very different results when applied to the same problem. It is not possible to know what priority rule will perform best a priori (Vázquez et al. 2013). However, P-SGS/MIN-SLK is a general-purpose algorithm. Our application to the resolution of all of the 140 problems in MPSPLib led us to conclude that the results we obtained were even better than other algorithms that had to be adapted ad-hoc to solve a particular problem.

6 Conclusions

In this work, we have presented the algorithm P-SGS/MIN-SLK. It is based on a heuristic proposed by Kolisch (1996) to solve the Resource-Constrained Project Scheduling Problem (RCPSP). We have adapted the heuristic by Kolisch to the multi-project case (RCMPSP). We have described the functioning of P-SGS/MIN-SLK and, for illustrative purposes, we have also presented how the algorithm deals with the scheduling of a simplified set of projects. In order to evaluate the performance of the algorithm, we used it to solve all of the 140 scheduling problems collected in a well-known repository of RCMPSP problems: the library MPSPLib.

Table 1 summarizes the performance of the algorithm. The complete benchmark can be found in the appendix to this article.

Table 1. Performance of PSGSMINSLK compared to other algorithms in MPSPLib

	PSGSMINSLK holds the best result	PSGSMINSLK is least as good as the best heuristic	The difference with the best result is smaller than 1%	The difference with the best result is smaller than 2%	The difference with the best result is smaller than 5%
Number of problems (out of 140)	22	38	54	71	108
Percentage	16%	27%	39%	51%	77%

We found that the algorithm P-SGS/MIN-SLK outperforms many other heuristics published in this library in spite of its simplicity. Evidence of that is the fact that it provides a better result than any other algorithm in the library in 22 of the 140 problems (i.e. 16% of the cases), and it performs at least as good as other algorithms in 38 of the 140 problems (i.e. 27% of the cases).

In practical terms, when considering the use of P-SGS/MIN-SLK to solve a multi-project problem, it should be noticed that it leads to powerful results even in those cases in which the top result of the benchmark is held by other algorithm. Concretely, we found that the difference between performance of P-SGS/MIN-SLK and the performance of the currently best algorithm in MPSPLib is smaller than 1% in 39% of the problems; smaller than 2% in over half of the problems, and smaller than 5% in 77% of the cases (Table 1). We would like to close by saying that this difference is smaller than 10% in 135 of the 140 RCMPSP cases in MPSPLib even though P-SGS/MIN-SLK is a general-purpose algorithm whilst some other algorithms on MPSPLib were built ad-hoc to solve concrete problems in the library.

In order to increase the usability of the algorithm, in future work we will enhance P-SGS/MIN-SLK's priority rule so that it also considers some practical criteria for companies when prioritizing some activities over others, such as financing constraints.

Compliance with ethical standards

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Conflict of interest. The authors declare that there is no conflict of interests regarding the publication of this paper.

Human and animals participants. This article does not contain any studies with human participants or animals performed by any of the authors.

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Appendix

The following table compares the performance of P-SGS/MIN-SLK and the performance of the current leading algorithm for each one of the 140 problems in MPSPLib. For this aim, the table shows two entries per problem expect in those cases where P-SGS/MIN-SLK holds the best result, where only one entry is shown, Notice that the 38 (out of 140) RCMPSP problems in which PSGSMINSLK holds the best result in TMS are shown in shaded cells.

The name of the problems in MPSPLib are conveniently codified so that their names reflect the number and the size of the projects. For example, the first problem is named mp_j30_a10_nr1 meaning the following: a multi-project problem (mp) composed of 10 projects (a10) each of which has 30 activities (j30). The term nr1 is simply a reference to distinguish different problems with the same number of project and activities. For example, all of the first five problems have 10 projects and 30 activities (nr_1 to nr_5) which differ in the start dates of the projects and the number of global resources (2, 1, 2, 3, and 1, respectively). In the last 80 problems of the list, the suffix _AC is added to the name of the problem, which means that all the resources of that problem are global.

ID	MPSPlib INSTANCE	NO. OF TASKS	NO. OF PROJECTS	NO. OF GLOB. RESOURCES	AUTHOR	TMS	DATE	METHOD
1	mp_j30_a10_nr1	30	10	2	Tony Wauters	188	8/3/10	HYPER
					Lopez-Paredes/Pajares/Villafañez	188	6/18/14	**PSGSMINSLK**
2	mp_j30_a10_nr2	30	10	1	Túlio Toffolo	109	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	114	6/18/14	**PSGSMINSLK**
3	mp_j30_a10_nr3	30	10	2	**Lopez-Paredes/Pajares/Villafañez**	243	6/18/14	**PSGSMINSLK**
4	mp_j30_a10_nr4	30	10	3	**Lopez-Paredes/Pajares/Villafañez**	143	6/18/14	**PSGSMINSLK**
5	mp_j30_a10_nr5	30	10	1	**Lopez-Paredes/Pajares/Villafañez**	187	6/18/14	**PSGSMINSLK**
6	mp_j30_a2_nr1	30	2	2	pérez/posada	70	10/28/13	GA-RK
					Lopez-Paredes/Pajares/Villafañez	71	6/18/14	**PSGSMINSLK**
7	mp_j30_a2_nr2	30	2	1	pérez/posada	58	10/28/13	GA-RK
					Lopez-Paredes/Pajares/Villafañez	61	6/18/14	**PSGSMINSLK**

8	mp_j30_a2_nr3	30	2	2	Trautmann/Homberger	65	5/14/08	MAS/PS
					Lopez-Paredes/Pajares/Villafañez	65	6/18/14	**PSGSMINSLK**
9	mp_j30_a2_nr4	30	2	3	Dietz/Homberger	54	5/20/08	CMAS/ES-STV
					Lopez-Paredes/Pajares/Villafañez	58	6/18/14	**PSGSMINSLK**
10	mp_j30_a2_nr5	30	2	1	Ameisenbär(Daniela)	58	2/14/11	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	59	6/18/14	**PSGSMINSLK**
11	mp_j30_a20_nr1	30	20	2	Birkner/Homberger	417	7/5/08	CMAS/ES-BORDA
					Lopez-Paredes/Pajares/Villafañez	425	6/18/14	**PSGSMINSLK**
12	mp_j30_a20_nr2	30	20	1	**Lopez-Paredes/Pajares/Villafañez**	278	6/18/14	**PSGSMINSLK**
13	mp_j30_a20_nr3	30	20	2	**Lopez-Paredes/Pajares/Villafañez**	304	6/18/14	**PSGSMINSLK**
14	mp_j30_a20_nr4	30	20	3	**Lopez-Paredes/Pajares/Villafañez**	183	6/18/14	**PSGSMINSLK**
15	mp_j30_a20_nr5	30	20	1	Tony Wauters	410	1/21/14	MINTWK
					Lopez-Paredes/Pajares/Villafañez	410	6/18/14	**PSGSMINSLK**
16	mp_j30_a5_nr1	30	5	2	pérez/posada	82	10/27/14	GA-RK
					Lopez-Paredes/Pajares/Villafañez	83	6/18/14	**PSGSMINSLK**
17	mp_j30_a5_nr2	30	5	1	Tony Wauters	79	6/14/12	GT-MAS
					Lopez-Paredes/Pajares/Villafañez	80	6/18/14	**PSGSMINSLK**
18	mp_j30_a5_nr3	30	5	2	Tony Wauters	103	6/27/12	HYPER
					Lopez-Paredes/Pajares/Villafañez	108	6/18/14	**PSGSMINSLK**
19	mp_j30_a5_nr4	30	5	3	Dietz/Homberger	76	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	76	6/18/14	**PSGSMINSLK**
20	mp_j30_a5_nr5	30	5	1	Dietz/Homberger	87	6/26/08	CMAS/ES-STV
					Lopez-Paredes/Pajares/Villafañez	88	6/18/14	**PSGSMINSLK**
21	mp_j90_a10_nr1	90	10	2	Dietz/Homberger	158	5/14/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	158	6/19/14	**PSGSMINSLK**
22	mp_j90_a10_nr2	90	10	1	Dietz/Homberger	128	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	132	6/19/14	**PSGSMINSLK**
23	mp_j90_a10_nr3	90	10	2	**Lopez-Paredes/Pajares/Villafañez**	213	6/19/14	**PSGSMINSLK**
24	mp_j90_a10_nr4	90	10	3	Dietz/Homberger	150	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	150	6/19/14	**PSGSMINSLK**
25	mp_j90_a10_nr5	90	10	1	Tony Wauters	230	6/11/12	GT-MAS
					Lopez-Paredes/Pajares/Villafañez	236	6/19/14	**PSGSMINSLK**
26	mp_j90_a2_nr1	90	2	2	Dietz/Homberger	88	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	88	6/19/14	**PSGSMINSLK**
27	mp_j90_a2_nr2	90	2	1	Túlio Toffolo	117	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	124	6/19/14	**PSGSMINSLK**
28	mp_j90_a2_nr3	90	2	2	Dietz/Homberger	114	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	115	6/19/14	**PSGSMINSLK**
29	mp_j90_a2_nr4	90	2	3	Dietz/Homberger	92	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	92	6/19/14	**PSGSMINSLK**
30	mp_j90_a2_nr5	90	2	1	Dietz/Homberger	121	6/25/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	121	6/19/14	**PSGSMINSLK**
31	mp_j90_a20_nr1	90	20	2	Tony Wauters	97	10/22/09	GT-MAS
					Lopez-Paredes/Pajares/Villafañez	110	6/19/14	**PSGSMINSLK**
32	mp_j90_a20_nr2	90	20	1	Túlio Toffolo	164	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	168	6/19/14	**PSGSMINSLK**
33	mp_j90_a20_nr3	90	20	2	Dietz/Homberger	122	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	122	6/19/14	**PSGSMINSLK**
34	mp_j90_a20_nr4	90	20	3	Dietz/Homberger	181	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	186	6/19/14	**PSGSMINSLK**
35	mp_j90_a20_nr5	90	20	1	**Lopez-Paredes/Pajares/Villafañez**	229	6/19/14	**PSGSMINSLK**
36	mp_j90_a5_nr1	90	5	2	Dietz/Homberger	79	5/14/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	79	6/19/14	**PSGSMINSLK**
37	mp_j90_a5_nr2	90	5	1	Dietz/Homberger	114	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	114	6/19/14	**PSGSMINSLK**
38	mp_j90_a5_nr3	90	5	2	Dietz/Homberger	138	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	140	6/19/14	**PSGSMINSLK**
39	mp_j90_a5_nr4	90	5	3	Dietz/Homberger	123	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	132	6/19/14	**PSGSMINSLK**
40	mp_j90_a5_nr5	90	5	1	Túlio Toffolo	153	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	162	6/19/14	**PSGSMINSLK**
41	mp_j120_a10_nr1	120	10	2	Dietz/Homberger	130	5/14/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	134	6/20/14	**PSGSMINSLK**
42	mp_j120_a10_nr2	120	10	1	Tony Wauters	248	6/14/12	GT-MAS
					Lopez-Paredes/Pajares/Villafañez	265	6/20/14	**PSGSMINSLK**
43	mp_j120_a10_nr3	120	10	2	Dietz/Homberger	142	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	146	6/20/14	**PSGSMINSLK**
44	mp_j120_a10_nr4	120	10	3	Dietz/Homberger	371	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	371	6/20/14	**PSGSMINSLK**
45	mp_j120_a10_nr5	120	10	1	**Lopez-Paredes/Pajares/Villafañez**	481	6/20/14	**PSGSMINSLK**
46	mp_j120_a2_nr1	120	2	2	Tony Wauters	155	6/28/12	HYPER
					Lopez-Paredes/Pajares/Villafañez	161	6/20/14	**PSGSMINSLK**
47	mp_j120_a2_nr2	120	2	1	Túlio Toffolo	133	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	140	6/20/14	**PSGSMINSLK**
48	mp_j120_a2_nr3	120	2	2	**Lopez-Paredes/Pajares/Villafañez**	275	6/20/14	**PSGSMINSLK**
49	mp_j120_a2_nr4	120	2	3	Túlio Toffolo	148	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	151	6/20/14	**PSGSMINSLK**
50	mp_j120_a2_nr5	120	2	1	Túlio Toffolo	108	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	118	6/20/14	**PSGSMINSLK**
51	mp_j120_a20_nr1	120	20	2	Túlio Toffolo	76	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	91	6/20/14	**PSGSMINSLK**
52	mp_j120_a20_nr2	120	20	1	Túlio Toffolo	204	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	221	6/20/14	**PSGSMINSLK**
53	mp_j120_a20_nr3	120	20	2	Túlio Toffolo	235	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	238	6/20/14	**PSGSMINSLK**
54	mp_j120_a20_nr4	120	20	3	Túlio Toffolo	203	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	207	6/20/14	**PSGSMINSLK**
55	mp_j120_a20_nr5	120	20	1	Túlio Toffolo	178	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	189	6/20/14	**PSGSMINSLK**
56	mp_j120_a5_nr1	120	5	2	Túlio Toffolo	75	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	83	6/20/14	**PSGSMINSLK**
57	mp_j120_a5_nr2	120	5	1	Túlio Toffolo	165	7/2/14	MATHEUR

					Lopez-Paredes/Pajares/Villafañez	181	6/20/14	**PSGSMINSLK**
58	mp_j120_a5_nr3	120	5	2	Dietz/Homberger	200	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	203	6/20/14	**PSGSMINSLK**
59	mp_j120_a5_nr4	120	5	3	Dietz/Homberger	188	5/10/08	RES
					Lopez-Paredes/Pajares/Villafañez	188	6/20/14	**PSGSMINSLK**
60	mp_j120_a5_nr5	120	5	1	**Lopez-Paredes/Pajares/Villafañez**	257	6/20/14	**PSGSMINSLK**
61	mp_j90_a10_nr5_AC1	90	10	4	Dietz/Homberger	688	5/16/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	689	6/23/14	**PSGSMINSLK**
62	mp_j90_a10_nr5_AC10	90	10	4	Dietz/Homberger	172	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	176	6/23/14	**PSGSMINSLK**
63	mp_j90_a10_nr5_AC2	90	10	4	Dietz/Homberger	732	5/16/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	736	6/23/14	**PSGSMINSLK**
64	mp_j90_a10_nr5_AC3	90	10	4	Dietz/Homberger	263	5/16/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	264	6/23/14	**PSGSMINSLK**
65	mp_j90_a10_nr5_AC4	90	10	4	Túlio Toffolo	667	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	683	6/23/14	**PSGSMINSLK**
66	mp_j90_a10_nr5_AC5	90	10	4	Dietz/Homberger	361	6/27/08	CMAS/ES-STV
					Lopez-Paredes/Pajares/Villafañez	368	6/23/14	**PSGSMINSLK**
67	mp_j90_a10_nr5_AC6	90	10	4	Dietz/Homberger	680	5/16/08	RES
					Lopez-Paredes/Pajares/Villafañez	685	6/23/14	**PSGSMINSLK**
68	mp_j90_a10_nr5_AC7	90	10	4	**Lopez-Paredes/Pajares/Villafañez**	390	6/23/14	**PSGSMINSLK**
69	mp_j90_a10_nr5_AC8	90	10	4	Dietz/Homberger	273	5/16/08	RES
					Lopez-Paredes/Pajares/Villafañez	275	6/23/14	**PSGSMINSLK**
70	mp_j90_a10_nr5_AC9	90	10	4	Túlio Toffolo	233	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	243	6/23/14	**PSGSMINSLK**
71	mp_j90_a20_nr5_AC1	90	20	4	Dietz/Homberger	446	5/16/08	RES
					Lopez-Paredes/Pajares/Villafañez	447	6/23/14	**PSGSMINSLK**
72	mp_j90_a20_nr5_AC10	90	20	4	Dietz/Homberger	483	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	487	6/23/14	**PSGSMINSLK**
73	mp_j90_a20_nr5_AC2	90	20	4	Dietz/Homberger	127	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	130	6/23/14	**PSGSMINSLK**
74	mp_j90_a20_nr5_AC3	90	20	4	Dietz/Homberger	159	6/12/08	CMAS/SA
					Lopez-Paredes/Pajares/Villafañez	167	6/23/14	**PSGSMINSLK**
75	mp_j90_a20_nr5_AC4	90	20	4	**Lopez-Paredes/Pajares/Villafañez**	365	6/23/14	**PSGSMINSLK**
76	mp_j90_a20_nr5_AC5	90	20	4	Dietz/Homberger	123	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	130	6/23/14	**PSGSMINSLK**
77	mp_j90_a20_nr5_AC6	90	20	4	Dietz/Homberger	236	5/16/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	244	6/23/14	**PSGSMINSLK**
78	mp_j90_a20_nr5_AC7	90	20	4	Birkner/Homberger	270	7/6/08	CMAS/ES-BORDA
					Lopez-Paredes/Pajares/Villafañez	274	6/23/14	**PSGSMINSLK**
79	mp_j90_a20_nr5_AC8	90	20	4	**Lopez-Paredes/Pajares/Villafañez**	157	6/23/14	**PSGSMINSLK**
80	mp_j90_a20_nr5_AC9	90	20	4	Tony Wauters	426	6/15/12	GT-MAS
					Lopez-Paredes/Pajares/Villafañez	439	6/23/14	**PSGSMINSLK**
81	mp_j90_a2_nr5_AC1	90	2	4	Dietz/Homberger	187	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	192	6/23/14	**PSGSMINSLK**
82	mp_j90_a2_nr5_AC10	90	2	4	Dietz/Homberger	105	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	110	6/23/14	**PSGSMINSLK**
83	mp_j90_a2_nr5_AC2	90	2	4	Dietz/Homberger	333	5/20/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	347	6/23/14	**PSGSMINSLK**
84	mp_j90_a2_nr5_AC3	90	2	4	Túlio Toffolo	160	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	174	6/23/14	**PSGSMINSLK**
85	mp_j90_a2_nr5_AC4	90	2	4	Túlio Toffolo	329	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	352	6/23/14	**PSGSMINSLK**
86	mp_j90_a2_nr5_AC5	90	2	4	Dietz/Homberger	72	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	72	6/23/14	**PSGSMINSLK**
87	mp_j90_a2_nr5_AC6	90	2	4	Dietz/Homberger	186	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	190	6/23/14	**PSGSMINSLK**
88	mp_j90_a2_nr5_AC7	90	2	4	Túlio Toffolo	330	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	345	6/23/14	**PSGSMINSLK**
89	mp_j90_a2_nr5_AC8	90	2	4	Túlio Toffolo	158	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	168	6/23/14	**PSGSMINSLK**
90	mp_j90_a2_nr5_AC9	90	2	4	Túlio Toffolo	329	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	352	6/23/14	**PSGSMINSLK**
91	mp_j90_a5_nr5_AC1	90	5	4	Dietz/Homberger	568	5/16/08	RES
					Lopez-Paredes/Pajares/Villafañez	572	6/23/14	**PSGSMINSLK**
92	mp_j90_a5_nr5_AC10	90	5	4	Dietz/Homberger	254	6/27/08	CMAS/ES-STV
					Lopez-Paredes/Pajares/Villafañez	258	6/23/14	**PSGSMINSLK**
93	mp_j90_a5_nr5_AC2	90	5	4	Túlio Toffolo	628	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	633	6/23/14	**PSGSMINSLK**
94	mp_j90_a5_nr5_AC3	90	5	4	Dietz/Homberger	317	5/16/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	341	6/23/14	**PSGSMINSLK**
95	mp_j90_a5_nr5_AC4	90	5	4	Túlio Toffolo	816	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	858	6/23/14	**PSGSMINSLK**
96	mp_j90_a5_nr5_AC5	90	5	4	Dietz/Homberger	256	6/12/08	RES
					Lopez-Paredes/Pajares/Villafañez	263	6/23/14	**PSGSMINSLK**
97	mp_j90_a5_nr5_AC6	90	5	4	Dietz/Homberger	568	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	572	6/23/14	**PSGSMINSLK**
98	mp_j90_a5_nr5_AC7	90	5	4	Dietz/Homberger	630	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	632	6/23/14	**PSGSMINSLK**
99	mp_j90_a5_nr5_AC8	90	5	4	Dietz/Homberger	317	5/16/08	RES
					Lopez-Paredes/Pajares/Villafañez	326	6/23/14	**PSGSMINSLK**
100	mp_j90_a5_nr5_AC9	90	5	4	Túlio Toffolo	808	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	860	6/23/14	**PSGSMINSLK**
101	mp_j120_a10_nr5_AC1	120	10	4	**Lopez-Paredes/Pajares/Villafañez**	763	6/24/14	**PSGSMINSLK**
102	mp_j120_a10_nr5_AC10	120	10	4	Dietz/Homberger	178	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	186	6/24/14	**PSGSMINSLK**
103	mp_j120_a10_nr5_AC2	120	10	4	Dietz/Homberger	378	5/16/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	379	6/24/14	**PSGSMINSLK**
104	mp_j120_a10_nr5_AC3	120	10	4	**Lopez-Paredes/Pajares/Villafañez**	471	6/24/14	**PSGSMINSLK**
105	mp_j120_a10_nr5_AC4	120	10	4	Dietz/Homberger	416	5/16/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	419	6/24/14	**PSGSMINSLK**
106	mp_j120_a10_nr5_AC5	120	10	4	Dietz/Homberger	390	5/17/08	RES

					Lopez-Paredes/Pajares/Villafañez	399	6/24/14	PSGSMINSLK
107	mp_j120_a10_nr5_AC6	120	10	4	Dietz/Homberger	384	5/16/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	389	6/24/14	PSGSMINSLK
108	mp_j120_a10_nr5_AC7	120	10	4	Dietz/Homberger	138	5/17/08	RES
					Lopez-Paredes/Pajares/Villafañez	143	6/24/14	PSGSMINSLK
109	mp_j120_a10_nr5_AC8	120	10	4	Dietz/Homberger	169	5/17/08	RES
					Lopez-Paredes/Pajares/Villafañez	174	6/24/14	PSGSMINSLK
110	mp_j120_a10_nr5_AC9	120	10	4	Dietz/Homberger	148	5/16/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	160	6/24/14	PSGSMINSLK
111	mp_j120_a20_nr5_AC1	120	20	4	Dietz/Homberger	380	6/13/08	CMAS/SA
					Lopez-Paredes/Pajares/Villafañez	380	6/24/14	PSGSMINSLK
112	mp_j120_a20_nr5_AC10	120	20	4	Birkner/Homberger	342	7/5/08	CMAS/ES-BORDA
					Lopez-Paredes/Pajares/Villafañez	345	6/24/14	PSGSMINSLK
113	mp_j120_a20_nr5_AC2	120	20	4	Dietz/Homberger	301	6/14/08	RES
					Lopez-Paredes/Pajares/Villafañez	306	6/24/14	PSGSMINSLK
114	mp_j120_a20_nr5_AC3	120	20	4	Lopez-Paredes/Pajares/Villafañez	968	6/24/14	PSGSMINSLK
115	mp_j120_a20_nr5_AC4	120	20	4	Dietz/Homberger	308	5/17/08	RES
					Lopez-Paredes/Pajares/Villafañez	314	6/24/14	PSGSMINSLK
116	mp_j120_a20_nr5_AC5	120	20	4	Dietz/Homberger	350	5/17/08	RES
					Lopez-Paredes/Pajares/Villafañez	351	6/24/14	PSGSMINSLK
117	mp_j120_a20_nr5_AC6	120	20	4	Lopez-Paredes/Pajares/Villafañez	863	6/24/14	PSGSMINSLK
118	mp_j120_a20_nr5_AC7	120	20	4	Lopez-Paredes/Pajares/Villafañez	813	6/24/14	PSGSMINSLK
119	mp_j120_a20_nr5_AC8	120	20	4	Lopez-Paredes/Pajares/Villafañez	364	6/24/14	PSGSMINSLK
120	mp_j120_a20_nr5_AC9	120	20	4	Dietz/Homberger	297	5/17/08	RES
					Lopez-Paredes/Pajares/Villafañez	300	6/24/14	PSGSMINSLK
121	mp_j120_a2_nr5_AC1	120	2	4	Túlio Toffolo	213	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	226	6/23/14	PSGSMINSLK
122	mp_j120_a2_nr5_AC10	120	2	4	Dietz/Homberger	92	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	100	6/23/14	PSGSMINSLK
123	mp_j120_a2_nr5_AC2	120	2	4	Dietz/Homberger	103	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	111	6/23/14	PSGSMINSLK
124	mp_j120_a2_nr5_AC3	120	2	4	Túlio Toffolo	178	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	183	6/23/14	PSGSMINSLK
125	mp_j120_a2_nr5_AC4	120	2	4	Túlio Toffolo	105	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	113	6/23/14	PSGSMINSLK
126	mp_j120_a2_nr5_AC5	120	2	4	Dietz/Homberger	95	5/16/08	RES
					Lopez-Paredes/Pajares/Villafañez	106	6/23/14	PSGSMINSLK
					Túlio Toffolo	212	7/2/14	MATHEUR
127	mp_j120_a2_nr5_AC6	120	2	4	Lopez-Paredes/Pajares/Villafañez	224	6/23/14	PSGSMINSLK
128	mp_j120_a2_nr5_AC7	120	2	4	Dietz/Homberger	101	5/16/08	RES
					Lopez-Paredes/Pajares/Villafañez	107	6/23/14	PSGSMINSLK
129	mp_j120_a2_nr5_AC8	120	2	4	Dietz/Homberger	178	5/16/08	RES
					Lopez-Paredes/Pajares/Villafañez	185	6/23/14	PSGSMINSLK
130	mp_j120_a2_nr5_AC9	120	2	4	Túlio Toffolo	96	7/2/14	MATHEUR
					Lopez-Paredes/Pajares/Villafañez	107	6/23/14	PSGSMINSLK
131	mp_j120_a5_nr5_AC1	120	5	4	Dietz/Homberger	581	6/13/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	600	6/23/14	PSGSMINSLK
132	mp_j120_a5_nr5_AC10	120	5	4	Dietz/Homberger	614	5/16/08	RES
					Lopez-Paredes/Pajares/Villafañez	628	6/24/14	PSGSMINSLK
133	mp_j120_a5_nr5_AC2	120	5	4	Dietz/Homberger	292	6/13/08	RES
					Lopez-Paredes/Pajares/Villafañez	302	6/23/14	PSGSMINSLK
134	mp_j120_a5_nr5_AC3	120	5	4	Lopez-Paredes/Pajares/Villafañez	532	6/23/14	PSGSMINSLK
135	mp_j120_a5_nr5_AC4	120	5	4	Dietz/Homberger	372	5/16/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	384	6/23/14	PSGSMINSLK
136	mp_j120_a5_nr5_AC5	120	5	4	Dietz/Homberger	615	5/16/08	RES
					Lopez-Paredes/Pajares/Villafañez	632	6/24/14	PSGSMINSLK
137	mp_j120_a5_nr5_AC6	120	5	4	Dietz/Homberger	576	6/28/08	CMAS/ES-STV
					Lopez-Paredes/Pajares/Villafañez	592	6/24/14	PSGSMINSLK
138	mp_j120_a5_nr5_AC7	120	5	4	Dietz/Homberger	284	5/15/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	298	6/24/14	PSGSMINSLK
139	mp_j120_a5_nr5_AC8	120	5	4	Lopez-Paredes/Pajares/Villafañez	527	6/24/14	PSGSMINSLK
140	mp_j120_a5_nr5_AC9	120	5	4	Dietz/Homberger	355	5/16/08	CMAS/ES
					Lopez-Paredes/Pajares/Villafañez	369	6/24/14	PSGSMINSLK