ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
Tome VI (Year 2013) – FASCICULE 2 [April–June]
ISSN 2067–3809

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MASS CUSTOMIZATION AS A PROJECT PORTFOLIO FOR PROJECT – ORIENTED ORGANIZATIONS

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ABSTRACT: The idea of combining Mass Customization to the Project Management area stems from their common characteristic of uniqueness. Project Management aims to meet the organization objectives by manipulating production phases and limited resources. Being a temporary endeavour, with a defined beginning and end, it undertakes to meet unique goals and objectives, to bring about beneficial change or added value. On the other hand, Mass Customization serves the newly emerged requirements of customized and personalized products. To this extent, we are going to consider and examine Mass Customization as a strategic goal of a Project-oriented Organization, which runs collateral projects, in order to achieve its final purposes. For such a kind of organization, different customized products are considered as multiple projects of a portfolio. Together with the limited resources, an integrated environment is composed where priorities and hierarchical rules produce alternative configurations, which coexist. The paper proposes a dynamic framework, to assist decision makers in project coordination processes with realistic parameters.
KEYWORDS: Mass Customization, Project Management, Project Portfolio, RCMPSP

INTRODUCTION

Mass Customization seems to be one of the most interesting and flexible manufacturing systems that aims to meet customers' needs under a much personalized matter. There is a great amount of companies, which adopt customization and personalization as their main strategy, aiming to overcome the ongoing and fierce economic crisis. Companies [1] with high openness and extroversion are, de facto, willing to pay the "forfeit" of maintaining their market share.

Customer-centred approaches imply that industrial products or even services have to be considered as unique and of high, both economic and social, importance due to their complexity and demanding production processes. Each ultramodern piece is, beyond question, a project encountered by companies, on the grounds that it frequently involves research or design carefully planned to achieve a particular aim. It is also a temporary system coexisting with the permanent organization and the commonplace tasks and procedures. As commonplace tasks can be considered those comprising Mass Production but on the contrary, Mass Customization embodies temporary organization concept.

Along these lines, there is a one-to-one relationship between products and projects, which, in sequence, leads to the Project Portfolio aspect. Regarding the fact that Mass Customization-friendly industries are likely to produce more than one customized product, there is an emerging need of technically manipulating multi-project circumstances, which will possibly empower empirical management.

To elaborate on Project Portfolio, it is "a set of all projects and programmes in a Project-oriented Organisation at a given point in time. It is a time-now-analysis. For organisations that have a large number of projects in their portfolio, it makes sense to have several portfolios for different types of projects" [2].

When an organization has to deal with a given number of projects, it predominantly encompasses obstacles concerning resource planning and time scheduling. As a matter of course, pertinent managers correspond to these critical points by using their experience, subjectivity and their instinct as well. Nevertheless, there is an acknowledged approach called Resource Constrained Multi-project Scheduling Problem (RCMPSP) dedicated to solve this kind of difficulties. Specifically, it involves the scheduling of activities of multiple separate projects, subject to precedence and shared resource constraints [3]. The aforementioned situation is an NP-Hard optimization problem having many applications in large constructions, complex production lines, and wide logistic chains and manufacturing Project Management.

NP-hard problems are optimization problems having no optimal solutions. The solution strategy usually utilizes heuristic algorithms, a rule of thumb, by taking into account several assumptions and finding an approximate answer, so as to decrease computational burden and improve efficiency or effectiveness. Efficient heuristics are suitable and viable alternative for many complex optimization problems with low complexity. Greedy heuristics take "short" decisions in each "stage" in order to find local optimals. By using the term "stage", we convey the scheduling of each corresponding task of one or more projects in a specific time slice.

The remaining of the paper is structured as follows: In Section 2, we briefly discuss RCMPSP theory, with a view to the reader's introduction to the field of multi-project management. Furthermore, the scope and the incentive of combining Mass Customization key principles and Project Management are presented in Section 3. We elaborate on the basics of RCMPSP in Section 4. In Section 5 we attempt to approximate the notion of the RCMPSP by pointing out the conceptual model, which represents an integrated framework including all the key elements, in order to schedule simultaneous projects. The last section recapitulates the facts and gravitates to the contribution to new complex manufacturing conditions.

INTRODUCTION TO RCMPSP

As mentioned before, Resource Constrained Multi-project Scheduling Problem involves the precedence constrained scheduling of two or more projects' tasks competing the same scarce resources [4]. Usually in practice, available resources are limited and expensive and organizations have more than one simultaneously active projects leading their resources into insufficient or overload conditions [3]. Its predecessor, Resource-constrained Project Scheduling is an extensively explored area, for those interested in single-project scheduling. On the contrary, in the present paper we strive to highlight the dynamic notion of managing the conflicting schedules of multiple projects.

In order to deal with the coexisting projects, the key tool is to detect and resolve conflicts concerning resources and time delays through a decision-making process. The basic decision options are prioritizing, crashing, shifting and releasing tasks [4].

In the literature, there are many different solution methods of the RCMPSP depending on the number, the attributes, the resources and the classification of the criteria used during the decision-making process. Priority-rule based heuristic algorithms combine one or more priority rules, which are going to be presented in Section 4, and schedule schemes. Famous priority rules use time measures, networking relationships and resource availability. Each activity belonging to a decision set, this is where a specific greedy algorithm takes place, obtains a priority rule that minimizes or maximizes an objective function, stated by the Project Manager. Usual objectives bear on the minimization of project delays, average resource utilization and tardiness penalties [3].

Regardless of the method used to solve this kind of problems, there is a pivotal course of action. By materializing priority rules, a priority list of activities is constructed in the planning phase, before any execution step, at the zero-time point. The steps taken are iterative, once the decision of the execution order depends on each period of decision. As a result, high computational effort is required to fulfil the amount of trials. In any period, when activities compete for specific resources, the chosen priority rule or rules are applied. However dynamic approaches have the capability to alter the precedence at each stage, by following up the execution phases. The competitive advantage of these efficient techniques is that they satisfy the non-deterministic nature of the real process.

Because of the vast amount of literature research and Project Manager's acquaintance referring to RCMPSP knowledge, which is up to a degree doubtful, we offer all the fundamental stages of applying the RCMPSP principles in situations where customized products are considered projects and constitute the so called Project Portfolio.

Problem specification

In practice, the possible obstacles to be met are stated as follows:

- *A regular project contains even thousands of tasks. The number depends on the areas of application and the size of the projects, which are about to be executed.*
- *Additionally, concurrent activities, belonging to different projects, claim the use of limited resources, which are going to be assigned according to their priorities, technical or qualitative. Some examples of resource constraints may be [4]: shared equipment and tools, staff with different qualification, working place with limited access capacity, etc. The resources, claimed above, belong to a Resource Pool, from which the Project Manager picks up personnel and materials, in order to transact a single project or a Project Portfolio.*
- *There are also customized exclusive constraints. When tasks have rigorous precedence relationships they cannot be executed at the same time [4].*
- *The dynamic nature of projects is of high importance, since tasks usually delay or finish ahead of schedule. There is also a possibility of staff and equipment shortage in special trades and finally delayed arrivals, replacements or set-up time.*
- *Conflicting schedules caused by shareable resources or constraints is the major issue to be examined and resolved in order for the multi-project scheduling to be practical, realistic and implementable. To this direction, it is vital to make assumptions based on the RCMPSP techniques.*

SCOPE AND INCENTIVES

This section aims to address the basic features of Project-oriented Organizations, in order to put up the foundations of correlating Project Management with Mass Customization and resource management.

Introduction to projects

The first step to verge on project's rationale is to define its environment. The environment in which projects operate can be summarized by the 5 Cs [5]. These, accordingly, are:

- Context - the external general influence on the organization in which the project is taking place.
- Complexity - the level of difficulty or complication of a piece of work called "project".
- Completeness - how much of the end requirement a project will deliver.
- Competitiveness - how many other organizations will compete to deliver that work.
- Customer focus - the expectation that customers will have and the needs to be met by the project's outcome.

Thereafter, at first glance, it is undoubtful that a customized product can be considered as a project to be developed in the above described environment. Moreover, Project Management Association of Japan states that a project refers to a value creation undertaking, based on a specific mission, which is completed in a given or agreed timeframe and under constraints, including resources and external circumstances. Some common themes of projects are evident here [5]:

- Unique - the exact project has not been performed before. The project has a degree of novelty and for this reason, projects are said to have aspects of uniqueness.
- Temporary - the project does have a beginning and an end and requires a group of talented and qualified people to carry out the tasks, this implies temporary organizations.
- Focused - the task of the project is to deliver a particular product, service or result, in other words to accomplish a specific mission.

Additionally to these three vital aspects, project characteristics, which bound together projects and Mass Customization, are shown in Figure 1. According to the experience, these characteristics should prevale in both projects and Mass Customization, in order to have a pure and solid project-oriented production system of customized products.

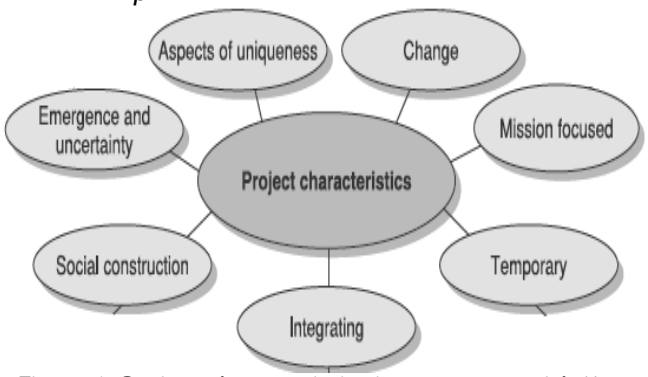

Figure 1. Project characteristics in agreement with Mass Customization principles

Another key element of projects is innovation. In projects, innovation is materialized by a group of people dedicated to investigate in practice innovative ideas.

Figure 2 [5] pictures the duties of temporary organizations (Project Management) and permanent organization (Line Management). In the figure, the trend is for the line AB to move downwards increasing the degree of innovation activities required from line managers. The result of that is a change in the role of line managers and a reduction of the gap between the role of line and project managers.

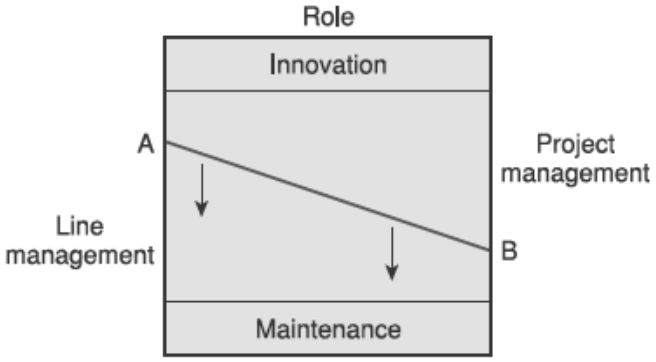

Figure 2. Innovation and maintenance activities in temporary and permanent organizations

More information about temporary and permanent organizations is given in the following sub-section.

Project-oriented Organizations

A Project-oriented Organization [2]:

- Uses "Management by Projects" as an organizational strategy.
- Uses Project and Programme Management to carry out extensive and complex processes.
- Has set up Project and Programme Portfolio Management.
- Has specific permanent organizations for integrating Project and Programme Management.
- Has an explicit Project and Programme Management culture.

A structural feature of Project-oriented Organizations is the use of temporary in addition to permanent organizations. On the one side, temporary organizations contribute to the differentiation of the organization, whilst permanent structures include expert pools, project portfolio groups and Project Management Office. Namely, temporary organizations provide organizational flexibility, to carry out projects or programmes and ensure organizational learning through project or programme potential. The coexistence of temporary and permanent organizations is illustrated in Figure 3 [2].

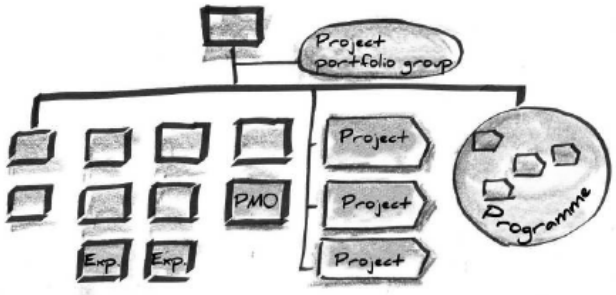

Figure 3. Permanent and temporary organization coexistence

In organizations that produce customized products, specialized knowledge and qualification are of high importance, so they indicate Resource Pools. And this is because Mass Customization differs from Mass Production practices and requirements concerning production lines, general management and marketing, push and pull systems, resource management, training of lower levels of employees. So to this extend,

temporary organizational Project Portfolio coordination tasks are crucial. On the other hand, and because of the fact that permanent organizations can and should not be resolved, they coexist to the temporary ones, assisting key processes. Hence both temporary and permanent organizational functions should take place for a systemic and holistic project-oriented approach of Mass Customization. The structural and organizational difference of permanent/conventional and temporary organizations is show in Figure 4.

The first half of the picture depicts an organization, it is not necessary to be a project-oriented one, that takes over a project (Pr.1), whilst the second half, refers to a Project-oriented Organization handling N simultaneous projects. The bunch of projects is the so-called Project Portfolio. If projects are interrelated they either refer to a chain of projects or a project network. When projects form a chain, they should have a sequential relationship, whilst it is about networks when projects are connected to some tasks due to technical reasons.

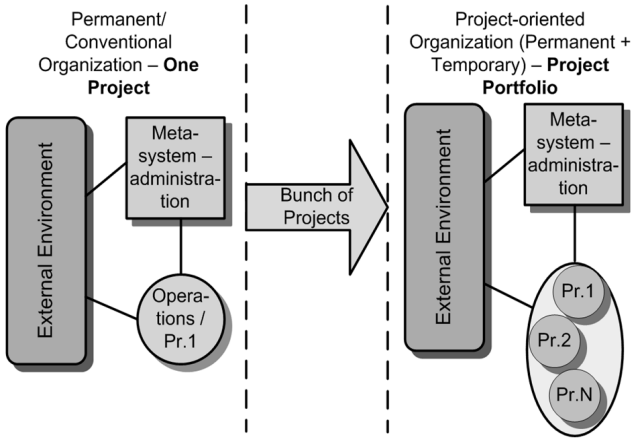

Figure 4. Customized Products illustrated as a bunch of projects in a Project-oriented Organization

In this picture the template of Viable System Modelling [6] is also used, because it serves to briefly depict the main ingredients of the organisational structure of any viable or autonomous system. The ingredients are Operations (circle), Meta-system (square) and External Environment (rectangular shape). Operations refer to production departments or units, while External Environment includes outer factors that influence or be influenced by the existing organization. As for the Meta-system, it represents the higher managerial staff and its name comes from the Greek word "system", in Greek "sistima" (it comes from the ancient Greek verb "συνίστημι", pronounced "sinistimi" and means coexist) [7]. The prefix "Meta-" is also a Greek word and denotes the sequence and superiority of managerial actions.

Organizational structures of a Project-oriented Organization are Project Management Office, Project Portfolio Group and Project Portfolio Management [2], which are usually integrated to the Meta-system. The Project Management Office provides Project Management support, assists in the fulfilment of personnel management and serves Project Portfolio Management. The Project Portfolio is the sum of projects undertaken by a Project-oriented Organization. The duty of optimizing Project Portfolio results and minimizing project portfolio risks belongs to the Project Management Office. As for the Project Management Expert Pool, it contains suitable qualified Project Management staff, to execute projects and programmes. Each Expert Pool has a manager responsible for recruitment and development of the Expert Pool staff and for knowledge management. Examples of an Expert Pool for IT organizations may be: software developers, operating system experts and so on.

Project Portfolio

A portfolio is a collection of projects or programmes grouped together to facilitate effective management efforts to meet strategic business objectives, such as Mass Customization adoption. These projects or programmes are not necessarily interdependent or directly related. Portfolio Management is the centralized management of multiple projects, programmes and possibly portfolios. This typically includes identifying, prioritizing and authorizing projects and programmes to achieve strategic business objectives. The group of projects and programmes within a specific business division could be an example of portfolio.

"Effective Portfolio Management is vital to successful product innovation" [8]. Under this scope, organizations make strategic choices (markets, products and technologies) in which they will invest in. It is about resource allocation, how companies will spend scarce engineering, R&D and marketing resources. It also focuses on project selection, depending on opportunities stemming from new products or development projects. Another significant aspect is the balance between numbers of projects, resources and capabilities [8].

The Project Portfolio Management decision problem includes product portfolio methods such as [8]:

- *Financial models and indices such as NPV and IRR.*
- *Probabilistic financial models: Monte Carlo simulation and decision trees.*
- *Options pricing theory: treats each stage of new product project much like purchasing an option on a future investment.*
- *Strategic approaches: the selection of the portfolio of projects is largely driven by the strategy of the business.*
- *Scoring models and checklists: on a variety of qualitative questions.*
- *Analytical hierarchy approaches: paired comparisons of projects and criteria.*
- *Behavioural approaches: to bring managers to a consensus.*
- *Mapping approaches or bubble diagrams: designed to allocate resources across the business units.*

Apart form these, the basis for Project Portfolio Management is a Project Portfolio database. This database should include information required for the composition of specific Project Portfolio reports. Typical reports include project portfolio budget, resource plan, risk matrix, progress graph and score cards. The fundamental tasks of Project Portfolio coordination are the following and Product Portfolio methods, as mentioned before, give effect to this direction [2]:

- *Optimize the result of the Project Portfolio as a whole.*

- Select the projects and programmes to be started.
- Interrupt and cancel projects and programmes, if necessary.
- Define project's and programme's priorities.
- Coordinate external and internal resources.
- Organize learning from and between projects and programmes.

In addition to those been mentioned, Project Portfolio Management corroborate and crave a blend of managerial and mathematical methodologies, by which resources will be properly allocated to projects and tasks.

According to literature [3], [4], [10-16], the predominant and holistic tool is the Resource Constrained Multi-project Scheduling Problem techniques, which is analysed in detail in Section 4.

Classic RCMPSP Basics

Assuming that we are examining a static multiproject environment, the prominent condition, to be analysed, is the resource transfer times, when scarce and expensive resources are to be shared between projects executed in different locations [3].

In large scale construction and manufacturing projects there are two types of shareable resources [17]. Machinery resources that are being transferred in order to execute activities in another project are first level resources and resources that perform the transport are the second level resources. A two level resource approach is consistent to the environment of many large budget technical and research projects, coming along the management of exceptional high cost or limited renewable resources.

It is apparent that in lower scale projects, such as conventional Mass Customization production projects, the classification of the resources into first and second level will arise due to the nature of the products. Some assumptions related to the RCMPSP parameters are considered in the following sub-sections.

Activities

- There are two non-pre-emptive activity types in each project. Activities executed using resources dedicated to the project and those executed by using shareable resources between more than one projects. The term "non-pre-emptive" conveys the image of assigning a resource to a project and keeping it immovable and dedicated to that project until the end of the activity.
- Deterministic durations, precedence constraints and resource requirements are known in advance.
- Activities executed by using shareable resources require only a certain resource type.
- Precedence constraints are defined only within projects.

Shareable Resources

- First and second level shareable resources are renewable.
- All second level resources are able to make only one movement at a time. A new movement will start after the completion of the current one.

Projects

- There are two or more concurrently executed independent projects, belonging to the Project Portfolio, competing for the same resources.
- There are no precedence constraints between projects.
- The project attributes are:
- Well defined objectives.
- It is carried out through a series or independent tasks.
- Utilizes various resources.
- It has a specific time-frame.
- It may be unique or one-time endeavour.
- It has a customer.
- It involves some degree of uncertainty.

Priority Rules

There is a great amount of priority rules to be used for the RCMPSP solution, but the most usual rules are the LST and EST [18].

- Latest starting Time (LST) is the latest possible time that an activity can start without extending the overall duration, due to the resource-unconstrained CPM [17].
- Dynamic Earliest Starting Time (D-EST) is the earliest possible time that an activity can start taking into account precedence and resource constraints [17], [18].

However a modular approach of the whole process will be able to use any rule. To solve this kind of problems, Graph Theory tools are helpful and the most common objective function is the minimization of the multi-project delay. Graph Theory is handy tool, because projects are traditionally depicted as directed acyclic graphs, just like Figure 5.

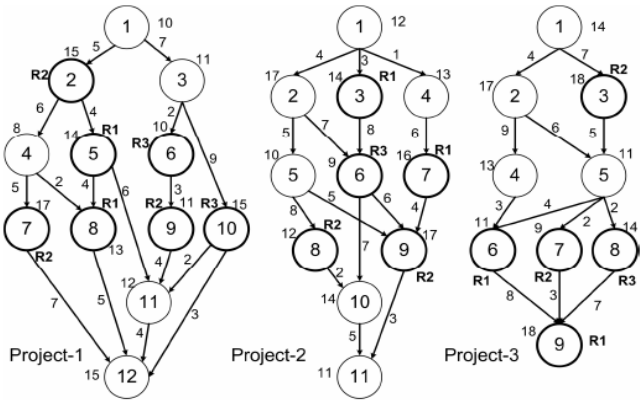

Figure 5. Multi-project graph

CONCEPTUAL MODEL FOR MANAGING PROJECT PORTFOLIO

The contribution of the presented paper is detected in the introduction and suggestion of a holistic context, which could assist and guide the Project Manager's decision-making, regarding multi-project and Portfolio Management. The following steps constitute a compact and comprehensive manual, founded on the grounds of RCMPSP and Project Portfolio Management dictations. In order to understand the notion of multiple projects, a simple three-project example is given in Figure 5.

The numbers inside the vertices, in Figure 5 [17], represent the activity numbering, while the numbers outside the vertices denote the execution time of each activity. Alphanumerical labels outside vertices denote the shareable resources (R1, R2, R3).

Project-1, Project-2 and Project-3 represent 3 different customized products undertaken by a company and they are to be considered concerning shareable resources and RCMPSP solutions. These

projects belong to the Project Portfolio of the Project-oriented Organization and need a strategic plan.

This strategic plan is going to offer a sufficient solution due to its NP-hardness. The solution will satisfy, to an extent, the objective function or functions under the subjective selection of priority rules.

THE PROPOSED FRAMEWORK OF MULTI-PROJECT ENVIRONMENT

One of the fundamental provinces that an engineer should address, in such a kind of RCMPS problems, is strictly delimiting the problem via the mathematical formulation of the multi-project scheduling. This rationale is a customary one for the known Project Management software (e.g., MS Project, Primavera). The critical point, due to which a Project Manager is assessed, is whether the planned Work Break-down Structure (WBS) and resource allocation are in accordance with the actual and real time execution process, or not.

Unfortunately, manager's subjectivity cannot be controlled or forecasted, therefore, it is up to him/her to aptly assign resources to work packages, so as to avoid resource conflicts. Pursuant to Project Management main idea, the arrangement of possible resource conflicts is made by the Resource Levelling technique. This technique embodies priority rules application combined with the approval of the most sensible scenario.

Referring to task requirements, resources may be global or local, where the former is a matter of shareable resources between projects, whilst the latter is about those dedicated to a single project. For its optimization a global resource requires either quantitative or qualitative objective functions.

As stated in RCMPSP solving strategy, in case of having, for example, three parallel product development projects (see Figure 5) the first step is to make a list, which includes tasks and the corresponding resources, global or local, from all three projects. In case of being global, availability should be investigated.

The questions that emerge are: Under which criteria will availability be investigated and when will the resource be available? The answer is straightforward and relates to the objective functions. To elaborate on this, objective functions may include time, cost or project priorities (e.g., ready for execution). Some time-related rules are stated in sub-Section 4.4. However, owing to flux scheduling, a change of the rule would be helpful, if needed. And this explains the dynamic side of the proposed methodology. In dynamic systems there aren't any mathematical models to provide a solution, hence conceptual models are the only to equip managers and engineers with decision making supporting tools. To this direction, the steps should be traced are:

- *Specify entities and their attributes: Entities in Project Management are two. The first one is the project itself and the second one is the resources. Tasks are not to be considered as a separate entity, but they are examined as part of projects.*
- *Set the objective function(s): Minimization or maximization of time, cost or other factors, as stated by the decision maker.*
- *Split the amount of resources into global and/or local: Global resources are those, which affect the multi-project scheduling, since local resources are taken for granted, in advance. Because of this, rules referring to local resources are stable and predefined in the planning phase.*
- *Pick deterministic and non-pre-emptive priority rules: Because the project is still in its planning phase, where circumstances are considered stable. Dynamic scheduling takes place in the phase of execution. However, in early states, such as the planning phase, the decisions to be made are deterministic. To this extent, the Project Manager chooses the rules, supposing that they will adequately meet project needs. Otherwise he/she changes the rule, during execution. Generally, rules refer to tasks, projects and resources. Rules can be chosen from one or more of the above categories. Referring to tasks, activities take priority values based on their features (e.g., shortest processing time first, minimum slack time first). Additionally, priority values are based on projects to which they belong or according to the special characteristics of each project (e.g., shortest activity from shortest project first). Finally, the availability of resources, the type of resources and their combination also affect priorities (e.g., maximum total work content rule). Critical activities are usually of high priority. Specifically, priority rules are:*
  - *As soon as possible (ASAP) - relates to the total execution time of the project.*
  - *As late as possible (ALAP).*
  - *Shortest activity first.*
  - *Mostly available resources are consumed first.*
  - *Minimun slack time first.*
  - *More interconnected critical tasks first.*
  - *More successive taks first.*
  - *First-come-first-served (FCFS) - ready tasks are to be put through first.*
  - *Last-come-last-served (LCLS).*
  - *Arbitrarily - depending on Project Managers subjectivity and qualitative criteria (e.g., customer's significance to the company).*
- *Give priority and execute the task(s), which derived from the rules. In each iteration, several pairs of resources - tasks are examined and finally scheduled to be executed. This phase is the execution phase, and in many cases rescheduling is very possible to happen. In this final step, and according to the rules been chosen in the planning phase, a list with the most crucial tasks and their resources is shaped. This list supports the Project Manager's decision, regarding the sequence of tasks to be performed.*

Figure 6 represents the rudimentary steps described above. In order to be comprehensible, this introductory flow-chart is divided into three major steps:

- *the pre-project phase,*
- *the planning phase, and*
- *the execution.*

The RCMPSP methodology is mirrored in the rule determination phase.

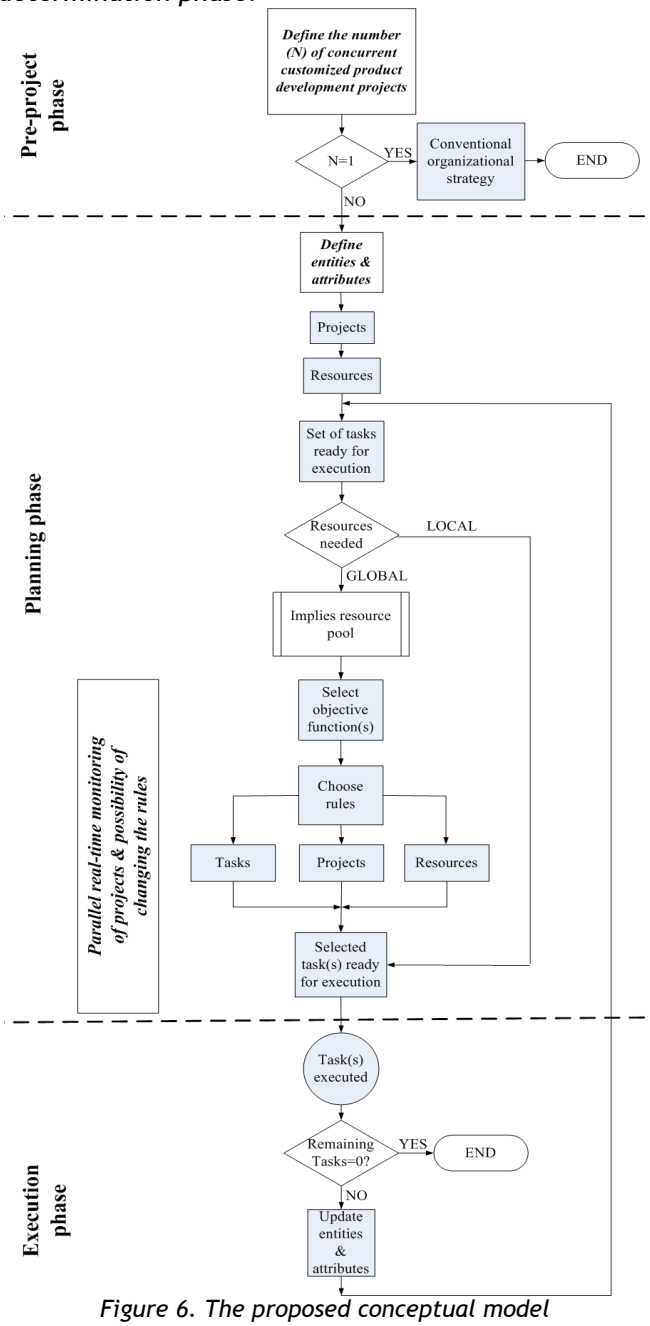

Figure 6. The proposed conceptual model

This model, as been previously mentioned, is materialized by the use of Project Portfolio Management best practices and delimited by a triple of resources posed by RCMPSP standardized solution. Future and further applications and experiments will empower the proposed method and could aid to the direction of a more engineering and absolute resource-related decision making.

CONCLUSIONS

When it's all been said and done, according to Project Management experts [19], a project is unique under the scope of resources, goals, customers, attitudes, human effort, networking, row of processes and so on. This explains why Mass Customization and Project Management are closely bound together. Thus, by bearing in mind the fact that customized products are unique by nature, a common basis for examining them as a united and solid strategy is formed and provided too.

This papers aims to achieve a "change in the paradigm", i.e., imbue Mass Customization with a renewed logic and an algorithmic viewpoint, to direct toward a well-known and widely tested technical approach.

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ISSN: 2067-3809 [CD-Rom, online]