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From the Editor

According to data from Ulrich's International Periodicals the total number of active refereed journals is over 15,000 in 2005. E-journal growth has also been dramatic, growing to 2500 in 2004. The process by which journals were published and distributed remained essentially unchanged for hundreds of years. The digital revolution changed things by making it possible to provide access directly to ideas recorded in journals from anywhere and at anytime.

The mission of the Walden University School of Management is to shape the direction of the 21st Century by advancing the knowledge and worldwide practice of management and leadership through the applied research. Peer review is a well-accepted indicator of quality scholarship and the E-journal format provided a way for us to address share our leadership through applied research. As a result, we created the International Journal of Applied Management and Technology, an on-line refereed journal, sponsored by the School of Management of Walden University. A number of recognized researchers in the field will evaluate a manuscript and recommend its publication, revision, or rejection. Articles accepted for publication through a peer review process implicitly meet the discipline's expected standards of expertise

Since our inaugural issue in November 2003, the International Journal of Applied Management and Technology has experienced dramatic growth and major improvements in several areas. We developed a copy protected software application that automates the process of manuscript submission, distribution and communication with authors, reviewers and staff. This software has significantly enhanced our interaction with stakeholders and eliminated a backlog of manuscripts in the publication pipeline.

Submissions have increased 400% since our first issue. The numbers of hits at ijamt.org were as high of 3000 per day with an average of about 500 per day during 2005. The Journal is fulfilling its objective of publishing excellent articles of broad interest to the community. By retaining its longstanding commitment to fairness and objectivity in the editorial process and to excellence as well as balance across our field, we aim to enhance its position as a premier journal in the field.

We also held our first International Conference on Applied Management and Decision Sciences: Building a Research Agenda for the 21st Century, held at the University of Georgia in Athens, Georgia on January 23-24, 2005 with 125 attendees. Conference proceedings are published and are available online (http://www.amdsconference.org . All authors were invited to present at the conference if their papers were accepted.

The conference and the journal support the mission of the Walden University School of Management to shape the direction of the 21st Century by advancing the knowledge and worldwide practice of management and leadership through the applied research. Both address scholar-practitioners' applied management research toward positive social change. They address topics from theory and analysis to practical strategies for action. In so doing, the conference and the journal will help define the important and complex questions facing 21st century managers and provide some initial answers to these questions.

Larry Beebe, PhD
Editor, iJAMT

Contents

About Determining the Professionalisation Level of Project Oriented Companies

Remco Meisner, PinkRoccade Atribit B.V.

Abstract

At PinkRoccade Atribit a model describing the professionality level of project-oriented companies has been developed: PPW. Determining the level of professionalisation in project-oriented companies on the basis of this PPW model at PinkRoccade Atribit usually is done by conducting interviews. This requires an effort by knowledgeable staff from both the researching party and the investigated party, which often is as difficult to arrange as it is costly. This study was an investigation of whether it is feasible to determine the PPW professionalisation level by using an eForm questionnaire. It was predicted that this eForm questionnaire approach would equally well reveal the maturity level in organisations. The research showed this prediction correct. In the process, also a proper functioning eForm as well as two *in situ* interview guides were developed.

Keywords

Project Quality, Organisational Professionalisation, Professionality Leveling, Questionnaires

Introduction

21st Century business requires companies to be able to rapidly adjust their operations in order to deal with the market changes that we're increasingly getting used to. Where in the past companies have been allowed sufficient time to traditionally take on a new production method, software tool, organisational structure a.s.o., today companies not only have to deal with speedy variations in the market demands, they at the same time have to keep ahead of competition. Competition that is not far behind them, looking for a weak spot. Organisations today are uninterruptedly trying to find ways to outsmart each other and this boosts the demand for flexibility in the way the business is organised.

Flexibility is improved greatly by introducing such changes the project-oriented way. Projects, 'short term grouped activities', allow 21st century organisations to obtain the required results (organisational changes – which can be just about anything from new software up to and including a new marketing approach) while (i) staying in control and (ii) such efforts taking a predetermined amount of time and budget.

In order to be able to optimally deal with the project oriented approach, organisations will need to know their actual maturity level. How 'healthy' are they? Which type of projects will they be able to deal with? When will a change require help from external specialists? Does the determined maximum complexity level suit their needs or do they need to improve their abilities? What *is* the optimum maturity for their organisation and what do their competitors in fact undertake in this area? Are they still ahead of the predators?

Hence the need for a way to determine the maturity of organisations dealing with projects. It will have to be possible to repeat such a measurement, as we will want to see progress while we improve our organisational maturity. This is what was researched: Measuring organisational maturity, allowing for repetition, suitable for any kind of organisation.
Having determined the organisational maturity and considering how competitors are doing, the way we want to do business ourselves in the coming period and other such considerations – this all aids into finding the way our organisation should develop its abilities and its position in the delivery chain.

In 2001, the Dutch project management company PinkRoccade Atribit gathered its most experienced workers and started the development of a model describing project maturity. Research included close looks into the *Capability Maturity Model* (CMM, which focuses on software development), the *Project Management Maturity Model* (PMMM, project maturity) and developments by the *Instituut Nederlandse Kwaliteit* (INK) in combination with the *European Foundation of Quality Management* (EFQM), which last two are combined in a single model, which focuses on changing organisations. The development resulted in the *Professionalisering Projectmatig Werken* (PPW) model. This model shows characteristics and evidence indicating maturity levels.

The reasoning behind this step is in the changing market conditions. Organisations today have to deal with increasingly complex changes, such as reorganisations, that occur more frequently at what seems to be ever-decreasing time intervals. As a result of the increasing complexity and decreasing time intervals, the accuracy with which such changes are practically implemented more and more determine the ability to compete: If an organisation is sloppy in implementing an organisational change (or is unaware of the necessity), their competitors are quite willing to make a better job of it and at the same time attempt to absorb the customer base. Today, as described by Han van der Zee and Paul van Wijngaarden using the *Nolan Institute Stages Framework*, "the organisation's main goal in using IT is to reconfigure the scope and tasks of the business network involved in the creation and delivery of products and services" (1999, p. 36).

There until recently existed no described method using which the actual maturity level in companies according to the PPW model can be measured. Such a method is needed to provide researchers with sufficient insights about the organisational project maturity with the company under investigation. Ideally such a measurement method ought to demand as little effort (read: *investment*) as possible.

The most important hypothesis the study investigated was: Using a questionnaire (eForm) in order to determine organisational project maturity will provide equally reliable results in comparison to the method based on site interviews, which is dealt with by specialists at both sides of the table.

The main goal of the study was to validate the eForm survey instrument in the application of measuring organisational project maturity.

The thinking was that using an eForm survey would:

- Save costs: The eForm is an extremely cheap alternative for *in situ* interviews requiring participation of specialist staff of the interviewing partner and with the interviewed party.
- Not require presence of an experienced project manager: An eForm can be completed without the need for much assistance of expensive personnel.
- Be easy to handle: Setting the eForm up, getting the eForms completed and collecting the results are steps in an easy and repeatable sequence.
- Allow completion at any time and from almost any place: Respondents can pick any time to complete the eForm and may access it via the world wide web from nearly any location.
- Simplify the analysis of the results: Comparing findings is facilitated by analysing the standardized and interchangeable results.

Research Hypotheses

We wanted to find out in which way we can best determine project maturity for organisations, best being at the lowest costs in combination with acceptable or preferably good results. Companies such as PinkRoccade Atribit earn money by improving the way customers deal with continuous change. Their customers benefit equally well, because they're enabled to deal with continuous improvement to a degree that suits their needs, mostly by empowering employees in the way indicated by Stephen P. Robbins (2001, p. 16).

The two most important hypotheses were:

- We can determine project maturity according to PPW using questionnaires.
- These outcomes are valid.

Two secondary hypotheses were:

- A practical and accurate eForm can be developed.
- Practical and accurate interview guides can be developed.

Research Assumptions

It was assumed that the *in situ* interview would be the most reliable way to determine organisational project maturity. This interview, if well prepared and carefully conducted, would function as the basis on which to compare findings based on another approach.

Another most important assumption in relation to the *in situ* interview foundation was about the linemanager of a typical project oriented department in an organisation being able to provide correct details regarding the way in which projects in the company generally are realised. A third assumption was about the linemanager of the Human Resources department, or the Personnel & Organisation department, being able to detail the way staffing in the organisation and in the projects is realised.

Research Approach

The differences between the existing models and PPW were investigated and described, a summary of the findings is provided in the text to follow. This has been done in order to benefit from existing material as much as possible.

An internationally spread random group of potential respondents, employed by a diverse group of organisations, was invited to contribute to the research. Everyone willing to aid was given a unique, personal code with which to access the website holding the eForm.

Companies employing the *de facto* respondents were approached in order to set up an *in situ* interview with two of their line managers. The outcomes of these interviews would function as the reference to which, at a later stage, the eForm questionnaire outcomes were to be compared.

The completed eForm questionnaires and the *in situ* interview outcomes were anonymised, statistically analysed and compared. On the basis of the outcomes it was determined whether or not questionnaires of this sort could indeed be considered a proper replacement for *in situ* interviews.

Models Comparison

Existing models, such as CMM, PMMM, INK and EFQM cover organisational areas but are not intended to deal with the typical project oriented environment. Each of them splits up maturity into five levels, though INK and EFQM have a less straightforward approach and in the list you find a personal 'working interpretation', and we can compare these by using the overview in Table 1.

level	CMM	PMMM	INK/EFQM[1]	PPW
1	initial	common language	committed	activity oriented
2	repeatable	common processes	involvement	process oriented
3	defined	singular methodology	interaction	system oriented
4	managed	benchmarking	culture	chain oriented
5	optimising	continuous improvement	challenge	total quality

Table 1: CMM; PMMM; INK/EFQM and PPW – Compared

The organisational maturity indicated by each of these models allows improvement as a result of implementing certain measures, so that (L. Ruijs, 2000) the gap between the measured, actual maturity level and that of the ambition level gets reduced.

Except for the INK/EFQM model, all models recognise five levels of maturity in organisations. They all have different aims and interpretations, though. Regardless that fact, during the development of PPW and now again, performing research, it is important to (David Silverman, 2000, item 5, page 85) think lateral by not forcing ourselves to rigidly remain in the boundaries of PPW and if required explore relations between the diverse models.

In the next couple of sections, I'll briefly explain the most important characteristics with each of these models an, in that way, clearify the added value to the PPW model.

CMM

The brief CMM level description is listed in Table 2. The Capability Maturity Model, a.o. according to Bert Boesjes (2004, page V) is typically dedicated to software developed in organisations to support its daily work. It provides means to deal with the type of maturity topics that such environments typically will encounter. It was (Pankaj Jalote, 2000, page xi) developed by the Software Engineering Institute (SEI) at Carnegie Mellon University.

[1] in fact the maturity level approach in INK/EFQM differs from that of CMM, PMMM and PPW; the specified here is my interpretation.

Level	Name	Description
1	Initial	(James R. Persse, 2001, page 5) Totally process absent, or processes are in place and haven't been formally assessed yet. During a crisis especially, teams will abandon planned procedures and revert to on-the-fly, ad hoc coding and testing. The risk level is at maximum for organisations at this level.
2	Repeatable	(James R. Persse, 2001, page 6) Implementation and study of processes, repeat what works and discard what doesn't. This level is found at a 'conscious' organisation, able to learn and improve. This level is a project-focused tier.
3	Defined	(James R. Persse, 2001, page 7) The processes for planning, developing, and maintaining software across the organisation are documented. Here two new groups appear in the organisation. One is the training group. The other group is responsible for the organisation's software process activities.
4	Managed	(James R. Persse, 2001, page 8) Process definition: Gauging the effectiveness of the defined processes with an eye toward continuous process improvement. The organisation sets quantitative (i.e. measurable) goals both for software products and processes.
5	Optimising	(James R. Persse, 2001, page 9) At level 5 the organisation is in a state of continuous improvement because its members are consistently striving to improve the range of their process ability.

Table 2: CMM Levels and Descriptions

Typical is the link between software-targeted organisations and the project focus at CMM level 2 (*Repeatable*), which emphasizes CMM is targeted towards the *organisational* aspects of a software development environment, rather than – like PPW – the *project maturity*.

Many of the relations between levels and the way these can be observed in organisations using (Pankaj Jalote, 2000, page xi) Key Process Areas (KPAs) are at a technical (i.e. software development) level, as can be seen from the overview in Figure 1, which combines the statements by James R. Persse (2001).

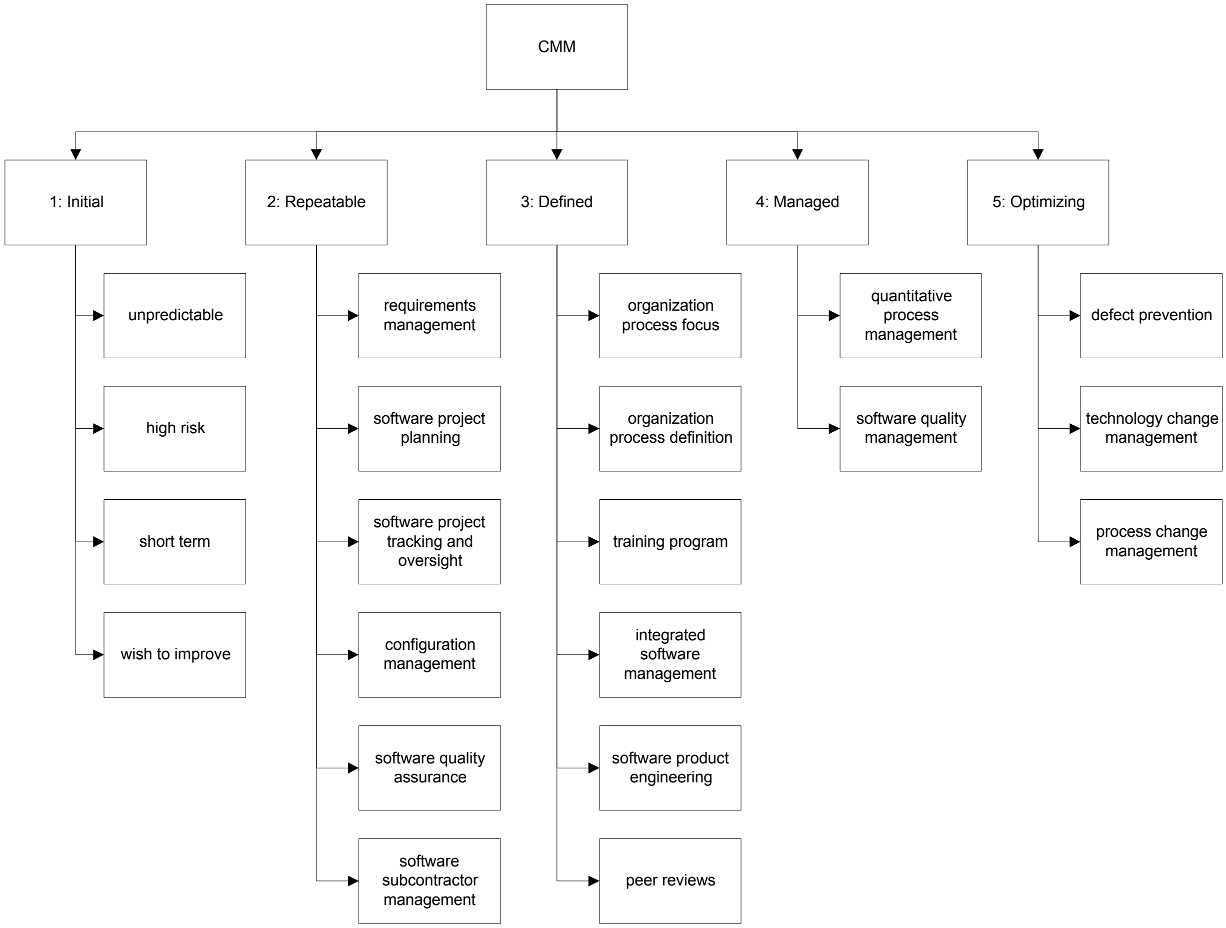

Figure 1: CMM Levels and Processes (according to James R. Persse (2001))

CMM is considered a *goal driven* methodology: It sets defined goals that an organisation is to pursuit and, while this is occuring, it compares realised Key Process Areas (KPAs) to targeted KPAs in conformity with what a.o. Pankaj Jalote advices in his *introduction* (2000, Table 1.1, page 10).

INK/EFQM

'The EFQM Excellence Model is a generic model for quality management, which is used in all types of organisations, regardless of sector, size, structure or maturity' (International Journal for Quality in Health Care, 2000, Volume 12, Number 3, page 192, http://intqhc.oupjournals.org/cgi/reprint/12/3/191.pdf). This model, maintained by the EFQM Organisation (2004, 'EFQM Excellence Model', http://www.efqm.org/model_awards/model/excellence_model.htm) is visualised in Figure 2. The INK/EFQM model does not define *Levels of Excellence* that allow for direct comparison to the five levels with PPW and CMM. This model describes levels of maturity with each of the boxes in Figure 2 independently. On top of that, there are different levels (and sometimes even a different number of levels) defined for the boxes. I have summarised the general idea with each level in Table 3 and in that approach attempted to stick to the five levels of maturity CMM, PMMM and PPW recognise. This is feasible as most boxes with INK/EFQM utilise five levels, the only exceptions are the *Results* boxes that each deal with only two different levels and *Policy and Strategy* (four levels).

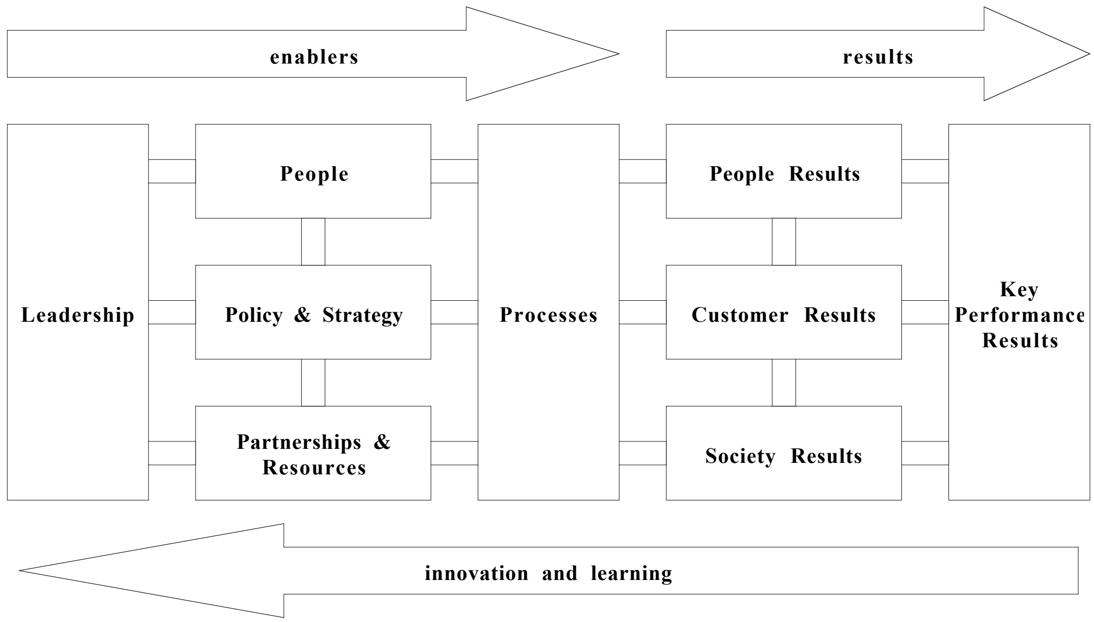

Figure 2: INK/EFQM model
(based on http://www.efqm.org/model_awards/model/excellence_model.htm (EFQM Organisation (2004, 'EFQM Excellence Model'*))*

The INK/EFQM model is dedicated to the quality of organisations in comparison to their environment and it aims for obtaining means using which companies can be compared as to their ability to adopt improvements and changes using learning and training.

Level	Name	Description
1	Committed	The organisation, or organisational unit, is at the beginning of the development. The emphasis will be on helping the organisation understand their current level of performance and to establish improvement priorities. (EFQM Organisation, 2004, *'Levels of Excellence'*, page 4, http://www.efqm.org/levels/downloads/info_%20levels.pdf)
2	Involvement	There's a structural approach to identify organisational strengths and areas for improvement. (EFQM Organisation, 2004, *'Levels of Excellence'*, page 4, http://www.efqm.org/levels/downloads/info_%20levels.pdf)
3	Interaction	Interaction with customers, partners and representatives of society. (EFQM Organisation, 2004, *'EFQM Excellence Model, Criterion 1'*, http://www.efqm.org/model_awards/model/DefinitionCriterion1.htm)
4	Culture	Embedding of the culture of excellence with organisation's people. (EFQM Organisation, 2004, *'EFQM Excellence Model, Criterion 1'*, http://www.efqm.org/model_awards/model/DefinitionCriterion1.htm)
5	Challenge	Identification and champion organisational changes. (EFQM Organisation, 2004, *'EFQM Excellence Model, Criterion 1'*, http://www.efqm.org/model_awards/model/DefinitionCriterion1.htm)

Table 3: INK/EFQM Levels and Descriptions

It incorporates certain aspects that are interesting for the PPW point of view – with its project maturity focus – though INK/EFQM has a quality focus. The aim is set towards finding strengths and weaknesses of the organisation and determining ways to develop it.

PMMM

Harold Kerzner's *Project Management Maturity Model* (PMMM) has an approach that somewhat looks like PPW. It describes maturity characteristics for a project driven organisation and it recognises five levels in this development. The maturity levels development, names and the typical improvements that lead an organisation from one maturity level to the next are visualised in (Harold Kerzner, 2001, Figure 4-1, page 42) Figure 3.

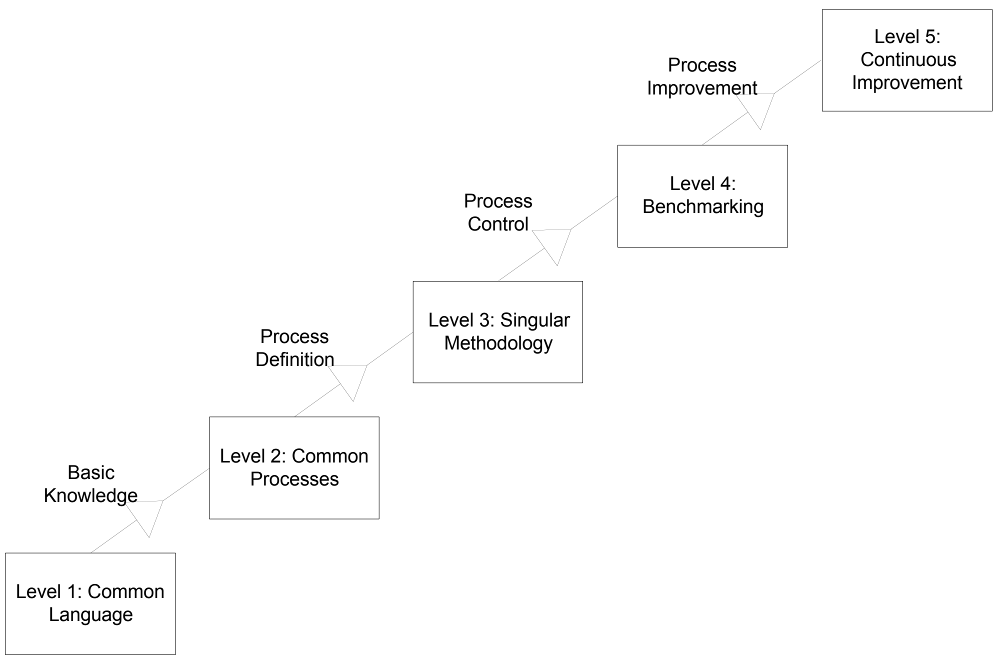

Figure 3: PMMM model (based on Harold Kerzner (2001, Figure 4-1, page 42))

The levels in this PMMM model are described in Table 4. The names of the maturity levels as well as in the associated descriptions clearly indicate the fact that PMMM is mainly about standardisation of the way projects are being handled. Though this by the CCTA and CGO is considered important when companies want to run successful projects, PPW expects a more holistic, organisation-wide perspective on maturity.

Level	Name	Description
1	Common Language	*'Organisation recognises the importance of project management and the need for a good understanding of the basic knowledge on project management and the accompanying language/terminology.'* (Harold Kerzner, 2001, *'The Foundation for Excellence'*, Level 1, page 42)
2	Common Processes	*The organisation recognises that common processes need to be defined and developed such that success on one project can be repeated on other projects.* (Harold Kerzner, 2001, *'The Foundation for Excellence'*, Level 2, page 42)
3	Singular Methodology	*The organisation recognises the synergistic effect of combining all corporate methodologies into a singular one, the centre of which is project management.* (Harold Kerzner, 2001, *'The Foundation for Excellence'*, Level 3, page 43)
4	Benchmarking	*Recognition that process improvement is necessary to maintain a competitive advantage. Benchmarking must be performed on a continuous basis.* (Harold Kerzner, 2001, *'The Foundation for Excellence'*, Level 4, page 43)
5	Continuous Improvement	*The organisation evaluates the information obtained through benchmarking and decides if and how this information enhances the singular methodology.* (Harold Kerzner, 2001, *'The Foundation for Excellence'*, Level 5, page 43)

Table 4: PMMM Levels and Descriptions

If we check PMMM in more detail, a.o. the following remarks in relation to PPW are important:

- PMMM observes the organisation as a whole, does not focus on areas.
- PMMM at all levels is aiming for uniformity in the way the company operates and in dealing with risks and barriers.
- PMMM allows overlapping maturity levels in an organisation (Harold Kerzner, 2001, *'Overlap of Levels'*, page 43).
- The assessment structure with PMMM requires responding to a lot of questions (Harold Kerzner, 2001, *'Assessment Questions'*, pages 51-66; 74-66; 87-96; 104-108 and 139-142).

PPW

PPW describes how companies will look like to the experienced observer with regard to the level of project oriented maturity. It does so by observing maturity driving perspectives and turning the results of this effort into six different points of view (I through VI), referred to as the ***pillars***. The pillars, described in Table 5 and visualised in Figure 4, are the result of extensive deliberations, involving several of the most experienced staff (project managers, programme managers, project directors, consultants, interim managers) at PinkRoccade Atribit.

PPW at the time it was 'frozen' did not provide any link between the description at one side and how to determine whether or not a company indeed fits such description at the other side. This I developed in order to suit my needs for this paper.

pillar	indication	brief description of the pillar
I	*The Project manager*	General observations in the company from the perspective of Project leaders, Project managers, senior Project managers. The interactions between these individuals and the rest of the company (Remco Meisner, 2000, §3, page 13).
II	*Methods and Techniques*	Which are the company's guidelines that bring results (methods) and what techniques (tools) are used to bring the guidelines into practice?
III	*The Customer*	What influence is input by the customer and to which degree is this customer, independently of the researched company, setting out its own route?
IV	*Realising the Project*	The processes leading to project results, the handling of improvements, role of involved staff.
V	*Knowledge Management*	What steps are taken to benefit from mistakes and improvements (i.e. the learned) as these are revealed while the staff is executing the work?
VI	*Project Support*	The degree to which there's a dedicated environment available to support returning administrative tasks that typically (recursively) come with project realisation.

Table 5: PPW Pillars

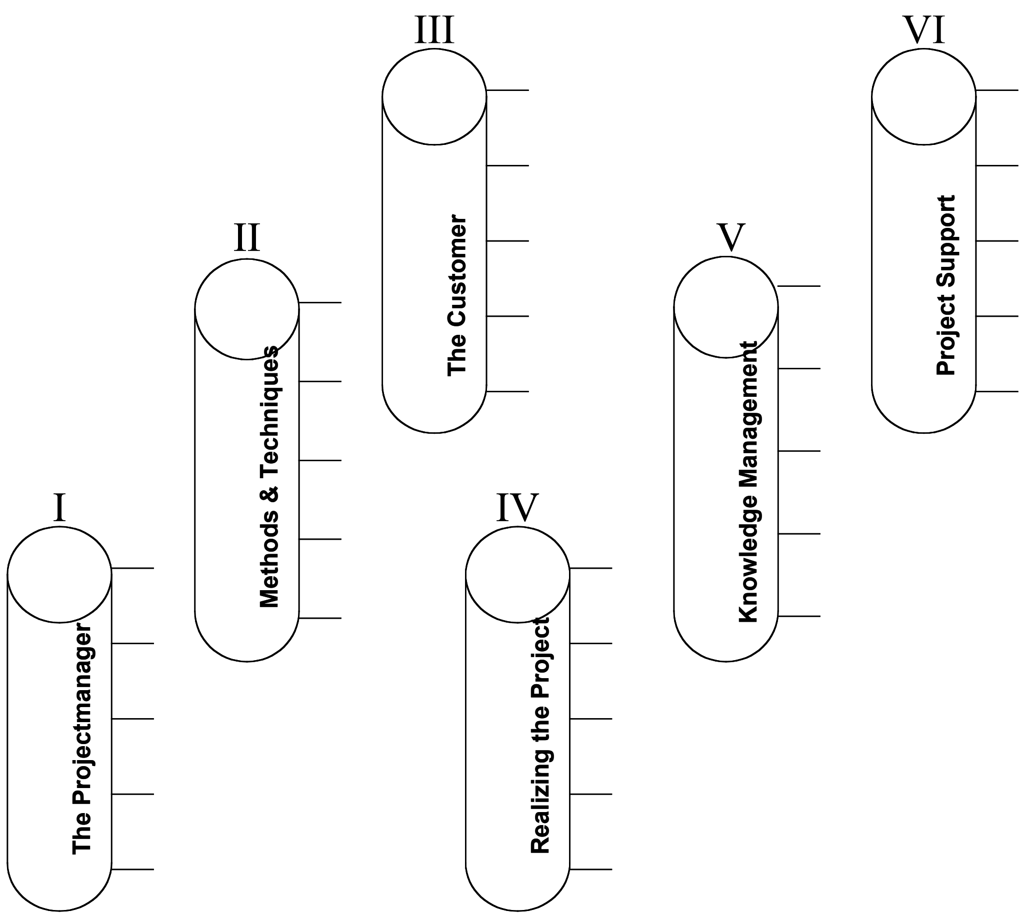

Figure 4: PPW Pillars Visualised

With each pillar there exist five levels of maturity, numbered 1 (one) to 5 (five). Of these, level 1 represents the lowest maturity level and level 5 the highest maturity level. The name indication and a brief description with each of these five levels is provided in Table 6.

level	indication	brief description of the effect
1	*activity oriented*	struggle to survive the project; glad to accomplish *any* result at all
2	*process oriented*	the main focus is on the process leading to the project results
3	*system oriented*	standard means are being used and a feedback loop is established
4	*chain oriented*	there's a link between projects and the rest of the chain
5	*total quality*	continuous loops, including external parties, feed improvements

Table 6: PPW Maturity Levels

Now the PPW model with its pillars has been enhanced with maturity levels and criteria describing perspectives, each pillar can be regarded taking all of this composition into account. The composite perspective for each pillar is similar to the example of pillar I: The Project manager, which is visualised in Figure 5.

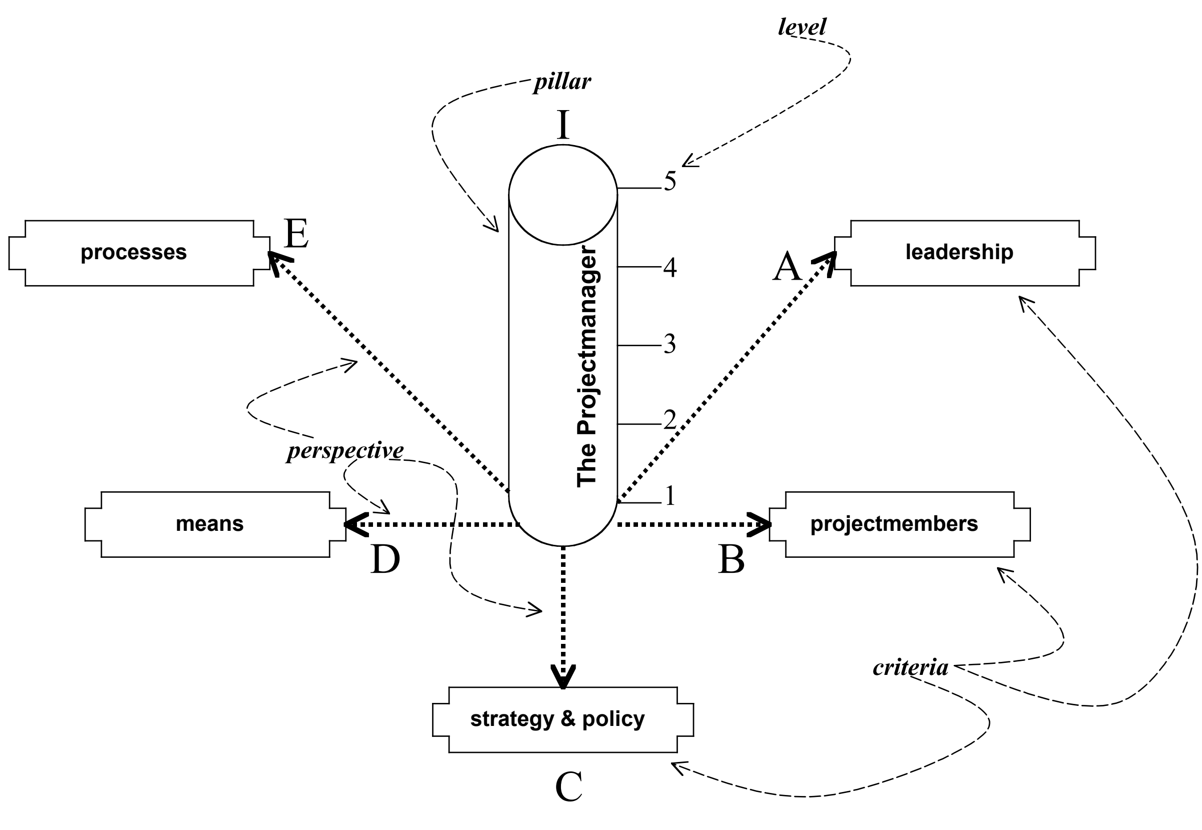

Figure 5: PPW Pillar I Composite Perspective

Combining the above PPW model information, with each of the six pillars and using the five criteria, the perspective descriptions can be made of what a company will look like to the knowledgeable outsider with each of the five maturity levels. I have with a group of colleagues described all of the 155 perspectives.

Method

The reference information was collected on the basis of two *in situ* interviews, using the two interview moulds in the course of the research specifically developed for this purpose:

- One interview with the line manager with a representative project oriented department.
- One interview with the line manager of the personnel department (HRM or P&O).

Each interview could be done in only 45 minutes for the fast version. Optimally it would require 60 minutes for the regular version. In practice, all interviewees went for the regular version. In some cases a little additional time was spent by mutually identifying quick wins for the organisation being researched.

The outcomes of these *in situ* interviews were combined and considered to accurately provide the organisational maturity, a reliable foundation to which the eForm questionnaires were next to be compared.

The eForm was made available via a website requiring respondents to enter a unique, personal access code. A screen snapshot can be seen in Figure 6. For one or two respondents, the technical infrastructure in companies appeared to not allow surfing to the eForm and for these cases a hard copy of the eForm had been made available and filled in.

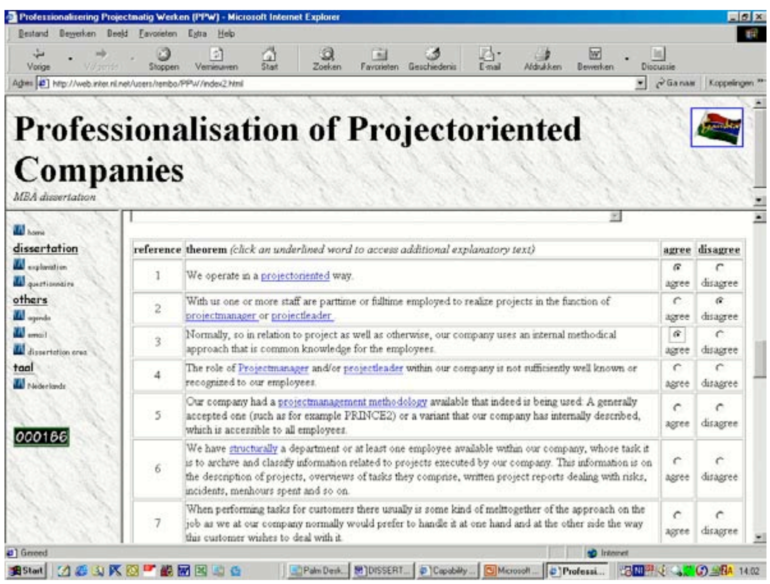

Figure 6: eForm Questionnaire appearance on the World Wide Web

It is made available in the Dutch and the English languages, so that respondents feel more at ease while entering their opinion on statements to which they can either *agree* or *disagree.*

The score with the questionnaire feedback has been noted in such a way that each of the *disagree* or *agree* ticked boxes corresponds with a crossing of a pillar and a maturity level, thus dealing the full five levels of maturity that may occur with each pillar.

Results

Companies that contributed to the research were split into five categories: *Services, Finance, Datacom, Education* and *Others*. This was done on the basis of the volume of responses.

The categorised quantities of companies are listed in Table 7. Also, with each of the categories in Table 8 it is indicated how many questionnaires have been returned. In these overviews, two Service Companies were discontinued in the period between the eForm inquiry start (Q4 in 2002) and the moment where this dissertation paper was completed on the basis of further research (March 2004).

	number of companies							
Category	**Dutch**		**abroad**		**total**	**discontinued**	
Services	32	91%	3	9%	**35**	2	6%
Finance	3	50%	3	50%	**6**	0	0%
Datacom	2	67%	1	33%	**3**	0	0%
Education	2	50%	2	50%	**4**	0	0%
Others	6	67%	3	33%	**9**	0	0%
total	45	79%	12	21%	**57**	2	4%

Table 7: Categorised Companies

The overview shows that by far most (91%) of the respondents were employed by Dutch companies, which in fact made me limit *in situ* research to companies with respondent indicated addresses in The Netherlands. Several of these companies as a whole operated internationally. Certain companies are subsidiaries of a larger constellation, which I have decided to refer to as Company Constellations. The relation between Category, Corporate Constellation and Company is illustrated in Figure 7.

	number of completed questionnaires						
Category	**Dutch**		**abroad**		**total**	**discontinued**	
Services	81	96%	3	4%	84	3	4%
Finance	4	57%	3	43%	7	0	0%
Datacom	7	88%	1	12%	8	0	0%
Education	2	50%	2	50%	4	0	0%
Others	5	83%	1	17%	6	0	0%
total	99	91%	10	9%	109	3	3%

Table 8: Categorised Questionnaires

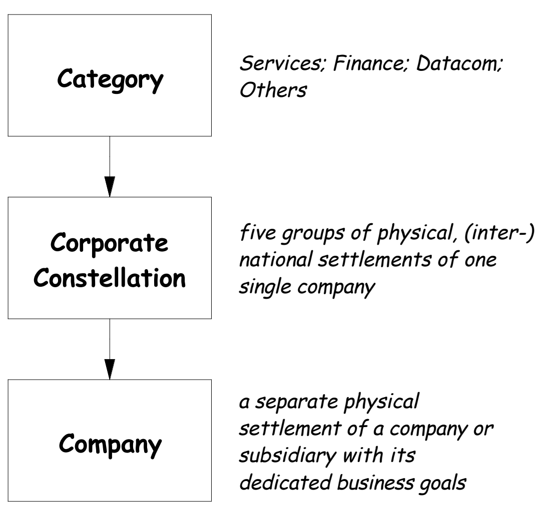

Figure 7: Category, Constellation and Company Relationship

The project maturity levels deducted from the returned questionnaires and from the *in situ* interviews are listed in Table 9.

company typology	**questionnaire maturity level outcomes**							***in situ* maturity levels outcomes**													
								HRM interview							**line management**						
pillars:	*1*	*2*	*3*	*4*	*5*	*6*	*t*	*1*	*2*	*3*	*4*	*5*	*6*	*t*	*1*	*2*	*3*	*4*	*5*	*6*	*t*
Overall	2	2	3	2	2	2	2	*only in situ results on Dutch companies available*													
Dutch Companies	2	2	3	2	2	2	2	2	2	2	3	2	2	2	3	3	3	3	3	2	3
Abroad Companies	2	2	3	2	2	2	2	*only in situ results on Dutch companies available*													
Services	2	2	3	2	2	2	2	2	2	2	3	2	1	2	3	3	3	3	3	2	3
Finance	3	3	2	3	2	3	3	3	2	2	3	1	2	2	2	2	2	3	1	2	2
Datacom	2	2	3	2	1	2	3	*not available*							3	4	4	4	3	4	3
Education	2	1	3	2	2	2	2	*not available*													
Other	2	1	2	3	3	3	2	4	3	3	4	3	2	3	4	5	5	4	3	2	4

Table 9: Maturity Levels Overview

This is a broad overview that allows only for limited interpretations, because of the variety of a.o. the respondent company categories and nationalities. Each of the company typologies has been enhanced with additional details in the course of the research.

The result of a detailed comparison involving the accuracy with which the project maturity for the pillars has been obtained is visualised in Figure 8. This presentation clearly indicates measuring maturity using a questionnaire certainly has potential, since the results obtained in this way in practice all appear to peak at around 80%-100%. There are obviously a few anomalities if we compare the shapes of these practically obtained graphs to what we in theory would prefer (a perfect normal distribution). Note, however, that this is not at all uncommon for this type of research.

The graphs show a red trend line based on the data that we obtained. It is this trend line that facilitates the finding that the sample distribution is not fully balanced.

Figure 8:Questionnaire Data Distribution

Interpretation of Results

The research regarding determining project maturity by using a questionnaire in comparison to the *in situ* approach brings us the following conclusions:

<u>Conclusion 1 with Hypothesis 1</u>

We can determine PPW project maturity using questionnaires. If we use questionnaires, these will produce results that provide us with an indication of the PPW project maturity.

<u>Note</u>: Research confirms this hypothesis. We can determine PPW project maturity with questionnaires. We should be careful in the way the questionnaire is constructed and not attempt to shift the targeted results by adding complexity. This conclusion indicates we can safely determine PPW project maturity using this relatively cheap and attractive means, provided we prepare it well.

Conclusion 2 with Hypothesis 2

The outcomes are valid. The questionnaire outcomes are valid and in conformity with reality. This is checked at the location of the company and in the media.

Note: Research confirms the hypothesis. The results produced using the approach described in this dissertation paper showed to be reliable and it can easily be improved further in order to increase the reliability. We ought to prepare a process to uninterruptedly develop the questionnaire approach. This conclusion indicates we can rely on the outcomes provided using the questionnaire, and we will keep it that way if we allow and support its development and improvement over time.

Conclusion 3 with Hypothesis 3

A properly functioning questionnaire contents and technique can be developed and successfully used in practice. Develop a questionnaire technique that produces meaningful results and indicate which developments are required to improve it.

Note: The hypothesis is confirmed. There has been a questionnaire content and technique developed that produces meaningful results. The contents of this questionnaire as well as the techniques used in association to it should now be subject to continuous improvement in order to uninterruptedly sharpen its accuracy. Suggestions in support of this have been formulated.

Conclusion 4 with Hypothesis 4

Properly functioning interview guides and techniques can be developed and successfully used in practice.

Note: In order to obtain a solid foundation to compare the questionnaire outcomes to with regard to project maturity, there has been an *in situ* interview guide developed and a technique to go with it. The contents of this *in situ* interview guide as well as the technique used in combination should now be in the same continuous improvement loop suggested in conjunction with conclusion 3.

Next Steps

The centre of follow-up after the completion of this dissertation paper is at disseminating the PPW model and the ways to measure and improve maturity levels within Atribit. This implies incorporating the approach into the existing processes.

The first steps towards taking it up in the processes are with:

- selection of key players;
- commercial preparation;
- place it in the routines at Atribit;
- start exploitation, this including improvements and developments.

Select a few internal **key players** that will be responsible for all aspects of the PPW model, the maturity determination and the knowledge thereabout internally as well as externally.

Note, that these key players not necessarily personally *handle* this all – they may just take on a co-ordinating role.

Through these key players **get a mechanism operating** to ensure the place of the approach at PinkRoccade Atribit, a.o. putting it in the '*routines and rituals'* (Claire Capon, 2000, page 154) as illustrated in Figure 9. Parts of this mechanism are in setting up sessions with specialists, improve and prepare the material available today in a technical as well as a commercial way.

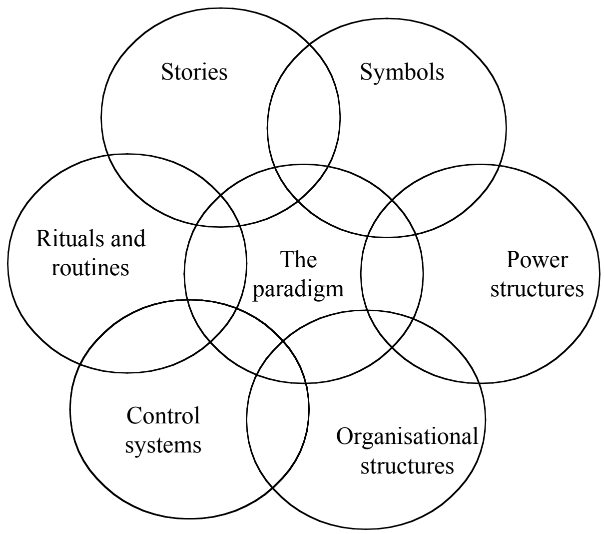

Figure 9: The Cultural Web
(based on Johnson, G. and Scholes, K. (1999) Exploring Corporate Strategies*, 5th edn., Prentice Hall Europe, in:* Understanding Organisational Context *by Claire Capon, Prentice Hall, 2000)*

Only after a successful dissemination within Atribit the **practical exploitation** of the approach be started with. It is suggested to firstly use the material in order to determine maturity levels in a controlled, secure group of companies: A Pilot. One or two PinkRoccade organisations would be a good starting point to practically test things out.

At the same time of this selection of key players, setting up the base material further and starting with the Pilot, the **commercial preparations** should commence.

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Productivity Measurement in a Continuous Production System: A Case Study

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Abstract

In spite of being one of the most repeated words in all spheres of activities, the concept of productivity remains elusive and enigmatic. People talk any sort of thing in the name of productivity and nearly all of them are correct. It appears that endless string of words may be coined using productivity as the suffix. In this application paper, the author makes an attempt to measure the productivity of a continuous production system comprising of various interconnecting plants by two approaches viz., Factor Productivity Indices Model (FPIM) available from the literature and an innovative model "Inter Plant Productivity Model (IPPM)" developed by the author. The developmental methodology, application part and the advantages & limitations of both the approaches are discussed in this application paper.

Keywords

Productivity, Continuous Production System, Factor Productivity Indices Model, FPIM, Inter Plant Productivity Model, IPPM

Introduction

Peter Mauson, Kenneth I Carlaw and Nathan Mc Lellan (2003) provide a review of conceptual and methodological issues in measuring productivity. In their work, attention is given to the concept of productivity and technological change. Susan G. Powers (1998) discusses the cyclical pattern of multifactor productivity and focuses on the measurement of capital input, specifically, the measurement of capital discards. William D. Nordhaus (2000) introduces a new approach to measure the industrial productivity based on income-side data that are published by the Burea of Economic Analysis (BEA). Charles Kui-Wai (2003) discusses the usage of Cobb-Douglas production function to measure the productivity of Chinese economy. But none of the methods discussed in the above mentioned works are appropriate in comparing the inter plant performance of a continuous production system having a chain of inter-connecting plants in such a way that the output from one plant becomes the input for the succeeding plant.

The methodology discussed for measuring the productivity in this application paper has been applied to a continuous process manufacturing unit comprising of several inter connecting plants viz., Steam Generation, Gasification, Ammonia and Urea. The output from one plant becomes the input for the next plant in the chain. The final product from the production unit is the nitrogenous fertilizer, "urea", popularly used in the priority sector of Agriculture. Coal is the principal raw material for the manufacturing process.

In such a complex manufacturing system, simply measuring the productivity as the ratio of the value of output (i.e. the final product) to the value of initial input fed to the process will not be helpful for any control purposes. In such a continuous manufacturing chain, it is desirable to compute the productivity at different stages of manufacture. This helps the production manager to identify the weak areas in the chain so that control action can be initiated to put the derailing things back on to the track. Quantification of productivity of different plants also would be useful as a process diagnostic tool for senior management's use in maximizing the overall production and productivity.

Two approaches have been discussed in this paper viz., Factor Productivity Indices Model for computing Total Productivity Measure (TPM) and Inter Plant Productivity Model for computing Plant Productivity Factor (PPF) for the measurement of productivity. While the former approach is from the available literature, William F. Christopher & Carl G.Thor (2004), Lipsey, Chichard G. & Carlow, Kenneth I (2004), Multifactor Productivity Trends (1998), the later approach is the model viz., Inter Plant Productivity Model (IPPM) designed and developed by the author for the measurement of productivity in continuous production systems.

Productivity

The Usual literature defines productivity conceptually as an attitude of mind and prevention of all kinds of waste. Mathematically, it is shown as a ratio of output to input, i.e.:

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

When both output and input are expressed in the same units, productivity reduces to a number. Quite often, it is also represented as an index as a percentage of output to input. It is also to be noted that both unit less as well as productivity in units (for example, coal mine productivity in tones per man-hour) are accepted criteria. There are valid reasons for use of each one of them. The fact remains that one should not be too rigid in the text of the definition and be pragmatic in its computation, application and interpretation.

Another very common and often mixed up problem is the distinction and relationship between production and productivity. Production is the output and is an absolute figure. It can be increased, inter alia, by proportionate increase in input. In such a situation, while the production increases, the productivity does not really go up. Productivity may be shot up by increasing production with constant or less than proportionate increase in input. Any inter-firm comparison of productivity should also ensure that the firms being compared in terms of factor productivity are indeed comparable. A firm having old machineries cannot be compared in terms of productivity with an other having the state-of-the-art technology even though they belong to the same industry sector. Only after ensuring this, one may infer about the level of productivities in the firm.

Factor Productivity Indices Model (FPIM)

In this method, productivity indices are computed for various factors of production viz., Labour, Equipment, Material and Other inputs. The following relations are used in computing the factor productivity indices.

$$\text{Labour Productivity (A)} = \frac{\text{Value of the total output in Rs/-}}{\text{Value of Wages \& Salaries in Rs/-}}$$

$$\text{Equipment Productivity (B)} = \frac{\text{Value of the total output in Rs/-}}{\text{Value of Repairs \& Maintenance and Depreciation in Rs/-.}}$$

$$\text{Material Productivity (C)} = \frac{\text{Value of the total output in Rs/-}}{\text{Value of all Materials Input including Power in Rs/-}}$$

$$\text{Other Inputs Productivity (D)} = \frac{\text{Value of the total output in Rs/-}}{\text{Value of other expenses in Rs/-}}$$

The Total Productivity Measure (TPM) of the production unit can be computed by integrating the above indices by using the relation – I, given below:

$$TPM = \frac{1}{1/A + 1/B + 1/C + 1/D} \quad \text{---- (I)}$$

The Productivity Indices, thus computed, are presented in the table 1:

Table 1 Productivity Indices of the Production Unit

Year	Labour Productivity	Equipment Productivity	Material Productivity	Other Inputs Productivity	Total Productivity Measure
1984—85	23.58	3.27	1.86	8.36	0.9940
1985—86	13.63	2.03	1.52	4.62	0.6951
1986—87	18.63	4.42	1.91	6.34	1.0400
1987—88	13.66	1.96	1.51	3.02	0.6100
1988—89	13.59	2.65	1.65	3.46	0.7430
1989—90	9.90	2.27	1.50	2.75	0.6362
1990—91	6.23	3.09	1.06	1.56	0.4834
1991—92	12.92	10.64	1.50	2.15	0.7672
1992—93	10.20	8.84	1.17	1.74	0.6096
1993—94	16.27	15.89	1.29	2.17	0.7350
1994—95	6.44	5.54	0.88	0.91	0.3889
1995—96	8.75	8.47	0.90	1.01	0.4285

The above method of computing the Total Productivity Measure (TPM) gives the performance of the entire production unit in an integrated way. The productivity indices of various factors of production indicate how efficiently and effectively these factors of production are put to use, in realizing the objectives of the organization. When these indices are computed every year, over a period of time, it helps in comparing the performance of these factors of production on a year-to-year basis. However, when this method is applied to a production unit comprising of various inter-connecting plants, it does not indicate the efficiency and effectiveness of individual plants. Hence the possibility of evaluating the plant wise performance is missing in this model. This is very essential since, it is required to identify the weak-link areas in the production unit so as to take appropriate action to keep the de-railing things on to the track. This is achieved through an innovative model viz., “Inter Plant Productivity Model (IPPM)” designed and developed by the author. The model, methodology, application part etc., are discussed in the following sections.

Inter Plant Productivity Model (IPPM)

A model known as “Inter Plant Productivity Model” has been developed by the author in order to eliminate the limitations in the Factor Productivity Indices Model, which computes the Total Productivity Measure (TPM) of the entire production unit. The new model IPPM enables the measurement of productivity factors for individual plants in the manufacturing chain of the production unit. The objectives and the computational details of the model are presented in the subsequent paragraphs.

Objectives of the model

The model evaluates the performance of individual plants based on three critical operating parameters and has the following objectives:

a) to improve the raw material consumption efficiencies.
b) to reduce the downtime of equipments.
c) to reduce the employee overtime element and
d) as a process diagnostic tool in maximizing the overall production and productivity

The Scheme

The model envisages computing three different efficiency measures in three different fronts in the production process viz., Specific Consumptions, Production Loss and Overtime Minimization. A factor known as Plant Productivity Factor (PPF) is computed which is based on three sub-factors viz., Specific Consumption Efficiency Factor (SCEF), Minimum Loss Factor (MLF) and Overtime Minimization Factor (OMF), duly depicting the performance measures in the three fronts discussed above. Depending on the relative importance, weightages are attached to all these sub-factors as indicated in Table 2:

Table 2: Sub-factors & weightages for the productivity model

Sl. no.	Productivity sub-factor	Weightage
01	Specific Consumption Efficiency Factor (SCEF)	0.40
02	Minimum Loss Factor (MLF)	0.40
03	Overtime Minimization Factor (OMF)	0.20
	Total	1.00

The Plant Productivity Factor is then computed using the relation – II, given below:

$$PPF = 0.40(SCEF) + 0.40(MLF) + 0.20(OMF) \quad \text{-------(II)}$$

Computational Details of the Model

The production unit under study is having four interconnecting operating plants and the computational procedure for computing SCEF, MLF and OMF are discussed in the subsequent paragraphs of this application paper.

Computation of Specific Consumption Efficiency Factor (SCEF)

The Specific Consumption Efficiency Factor for each plant is computed every month by taking the standard specific consumption and actual specific consumption of the inputs. Specific consumption is the consumption of an input per one unit of the output. In each plant, different inputs are fed to the production process. All the inputs are not of equal importance. For example, in Steam Generation plant, the value of the coal consumed is more than the value of power or fuel oil consumed. Therefore, higher weightage is given to coal when compared to power or fuel oil. Similarly in Gasification & Ammonia plants, the value of coal consumed is more than the value of power or steam consumed. Hence, more weightage is given to coal when compared to power or steam. In Urea plant, the value of ammonia consumed is more than the value of power or steam consumed. Therefore, higher weightage is given to ammonia. The details are presented in Table 3:

Table 3: Computation of SCEF of different plants

Plant	Inputs	Standard sp. consumption	Actual sp. consumption	Weighted ratio
Steam Generation	Coal	SC_1	SC_2	0.50 (SC1 / SC2) ---(a)
	Power	SP_1	SP_2	0.30 (SP_1 / SP_2) ---(b)
	Fuel Oil	SF_1	SF_2	0.20 (SF_1 / SF_2) ---(c)
	SCEF for Steam Generation plant			(a) + (b) + (c)
Gasification	Coal	GC_1	GC_2	0.50 (GC_1/GC_2) ---(d)
	Power	GP_1	GP_2	0.30 (GP1/GP2) ---(e)
	Steam	GS_1	GS_2	0.20 (GS_1/GS_2) ---(f)
	SCEF for Gasification plant			(d) + (e) + (f)
Ammonia	Coal	AC_1	AC_2	0.50 (AC_1/AC_2) ---(g)
	Power	AP_1	AP_2	0.30 (AP1/AP2) ---(h)
	Steam	AS_1	AS_2	0.20 (AS_1/AS_2) ---(i)
	SCEF for Ammonia plant			(g) + (h) + (i)
Urea	Ammonia	UA_1	UA_2	0.50 (UA_1/UA_2) ---(j)
	Power	UP_1	UP_2	0.30 (UP_1/UP_2) ---(k)
	Steam	US_1	US_2	0.20 (US_1/US_2) ---(l)
	SCEF for Urea plant			(j) + (k) + (l)

Thus, the SCEF is computed for each plant, every month.

Computation of Minimum Loss Factor (MLF)

In all continuous production systems, the loss of production will be booked on daily basis, against the equipments and plants responsible for the same. For example, on a particular day, there is a loss of production of 500 MT of the finished product due to the breakdown of some equipment (say, raw gas blower) in Gasification plant. Then, the loss of 500 MT is booked to the equipment "raw gas blower" of the gasification plant. Thus, the total loss in each plant can be obtained for every month. Subsequently, the percentage loss in each plant is calculated. For a given percentage loss, the Minimum Loss Factor (MLF) is obtained from the Table 4 depicting the severity of production loss.

Table 4: Percentage loss Vs. MLF

Percentage loss	MLF
0—10	0.90
11—20	0.80
21—30	0.70
31—40	0.60
41—50	0.50
51—60	0.40
61—70	0.30
71—80	0.20
81—90	0.10
91—100	0.00

Thus, the MLF is computed for each plant, every month.

Computation of Overtime Minimization Factor (OMF)

The manpower is deployed on overtime due to various reasons such as unforeseen breakdown of equipments during odd hours, absenteeism of employees etc., The rate of overtime wages is double the rate of normal wages. By proper planning, the overtime component can be minimized. For example, by adopting proper preventive and predictive maintenance policies, the equipment breakdowns can be minimized. Similarly by motivating the human resources, the industrial absenteeism could also be brought down. However, in continuous production systems, the overtime element can not be avoided totally. The overtime amount incurred in each plant is computed every month. Then, the overtime as a percentage of the wage bill of overtime-entitled employees is worked-out plant wise, every month. Subsequently, the Overtime Minimization Factor is obtained from the Table 5 for the corresponding overtime percentage.

Table 5: Overtime Percentage Vs. Overtime Minimization Factor

Overtime percentage	OMF
0	1.00
1—9	0.80
10—19	0.60
20—29	0.20
30—39	0.10
40—49	0.05
50 & above	0.00

Thus, the Overtime Minimization Factor is computed for each plant, every month.

Computation of PPF

After computing the SCEF, MLF and OMF, the Plant Productivity Factor (PPF) for each plant is computed every month, by using the relation - II presented in a previous section of this application paper. The PPF thus obtained for a period of five months is presented in table 6.

Table 6: Computation of Plant Productivity Factor (PPF)

Sl. no.	Plant / Factor	Month (1)	Month (2)	Month (3)	Month (4)	Month (5)	Average
1	Steam Generation plant						
	SCEF	0.7258	0.7661	0.7332	0.8519	0.7653	
	MLF	0.2000	0.5000	0.2000	0.8000	0.7000	
	OMF	0.0000	0.0000	0.0000	0.0000	0.0000	
	PPF	0.3703	0.5064	0.3733	0.6608	0.5861	0.4994
2	Gasification plant						
	SCEF	0.8089	0.8172	0.7196	0.9404	0.7187	
	MLF	0.8000	0.7000	0.8000	0.9000	0.7000	
	OMF	0.0000	0.0000	0.0000	0.0000	0.0000	
	PPF	0.6436	0.6069	0.6078	0.7362	0.5675	0.6324
3	Ammonia plant						
	SCEF	0.8089	0.8172	0.7196	0.9404	0.7187	
	MLF	0.9000	0.7000	0.8000	0.6000	0.5000	
	OMF	0.0000	0.0000	0.0000	0.0000	0.0000	
	PPF	0.6836	0.6069	0.6078	0.6162	0.4875	0.6004
4	Urea plant						
	SCEF	0.9277	0.9166	0.9159	0.9370	0.9000	
	MLF	0.9000	0.9000	0.9000	0.5000	0.9000	
	OMF	0.0000	0.0500	0.0000	0.0000	0.0000	
	PPF	0.7311	0.7266	0.7264	0.5748	0.7200	0.6958

Conclusions

The model, Inter Plant Productivity Model (IPPM), is developed on practical considerations and has the capability of "Inter-Plant" comparison of a manufacturing unit. This model facilitates the computation of the efficiency and effectiveness of the production process at each stage of manufacture. It would be useful as a process diagnostic tool for senior management's use in maximizing the overall production and productivity. This model has the capability of identifying weak-link areas in the production unit so as to enable the management to take appropriate corrective action in-order to improve the overall productivity of the organization. It is therefore recommended that the plant productivity factor can be computed for each plant every month, so that the weak areas in various plants can be immediately identified and suitable corrective action is taken.

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Simultaneous Scheduling of Parts and AGVs in an FMS Using Non-Traditional Optimization Algorithms

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Abstract

The current trend in manufacturing technology is towards creating fully automated and integrated manufacturing environments. A carefully designed and efficiently managed material handling system is of crucial importance in achieving the required integration. Automated Guided Vehicles (AGV) are among various advanced material handling techniques that are finding increasing applications today. They can be interfaced to various other production and storage equipment and controlled through an intelligent computer control system. In this paper, simultaneous scheduling of parts and AGVs is done for a particular type of FMS environment by using nontraditional optimization techniques such as Adaptive Genetic Algorithm (AGA) and Ants Colony Optimization (ACO). The problem considered here is a large variety problem (16 machines and 43 parts) and the objective function is combined objective (i.e. minimizing penalty cost and minimizing machine idle time). If the parts and AGVs are properly scheduled, then the idle time of the machining center can be minimized which in turn their utilization can be maximized. Minimizing the penalty cost for not meeting the delivery date is also considered in this work. These two contradictory objectives are aimed to achieve simultaneously by scheduling parts and AGVs using above non-optimization techniques and the results are compared.

Keywords

Adaptive Genetic Algorithm, Ants Colony Optimization, Automatic Guided Vehicles, Flexible Manufacturing Systems and Simultaneous scheduling

Introduction

Manufacturing systems are faced with ever-increasing customization and unstable demand. The traditional hierarchical control structures for shop floor (pre-release planning, scheduling, and dispatching and activity control) are often inflexible in responding to unexpected scenario changes and are thus not robust to system disturbances. FMS is the result of the growth in demand for product quantity and the concern for the product quality. Another major motivation for FMS has been based on the perceived need for manufacturing industry to respond to change more rapidly than in the past. FMS is a manufacturing philosophy and this sophisticated production system is based on the economies of scope wherein several part types are simultaneously resident in the system. Flexible Manufacturing Systems (FMS) are highly automated production systems, able to produce a great variety of different parts by using the same equipment and the same control system. Existing FMS implementations have already demonstrated a number of benefits in terms of cost reductions, increased utilizations, reduced work-in-process levels, etc. However, there are a number of problems faced during the life cycle of an FMS. These problems are classified into: design, planning, scheduling, and control problems. In particular, the scheduling task, the control problem during the operation, is of importance owing to the dynamic nature of the FMS such as flexible parts, tools, and Automated Guided Vehicle (AGV) routings.

Most research concerning the scheduling of the FMS has been focused on developing scheduling algorithms for a single objective. In a single-objective context some of the recent approaches have shown quite promising results. But real world scheduling problems naturally involve multiple objectives. This work is primarily concerned with scheduling of parts and Automated Guided Vehicles in FMS simultaneously. This work, however, consider multi-objective function i.e., minimize total penalty cost and minimize total machine idle time in the development of the scheduler to utilize resources maximally, thereby offsetting the high installation cost of equipment by using non traditional techniques such as Adaptive Genetic Algorithm(AGA) and Ants Colony Optimization (ACO) algorithm.

Previous Research Work

The high investment required for a FMS and the potential of FMS as a strategic competitive tool make it attractive to engage in research in this area. Due to this number of approaches and procedures are applied for scheduling the FMS. Scheduling of FMS has been extensively investigated over the last three decades and it continues to attract the interest of both the academic and industrial sectors. Various types of scheduling problem are solved in different job shop environments. Varieties of algorithms are employed to obtain optimal or near optimal schedules. Traditionally, the automatic generation of scheduling plans for job shops has been addressed using optimization and approximation approaches. Optimization approach is the theoretical research dealing with optimization procedures. Mathematical programming models, which are based on simplified assumptions for the system under study, are specific to individual manufacturing enterprises and processes. These models also require a high degree of accuracy in the data used. Operating an FMS is an activity with multiple criteria. Some authors have brought in these criteria in their modeling.

Buzacott and Yao (1986) presented a comprehensive review of the analytical models developed for the design and scheduling of FMS. In this approach, the researchers have cast the problem into an optimization model. They strongly advocate the analytical methods as giving better insight into the system performance than the simulation models. Wu and Wysk (1988) described a multi-pass real-time scheduling algorithm, in which discrete simulation in combination with an expert system and straightforward part dispatching rules in a dynamic fashion was employed. Lee and Jung (1989) formulated a part selection and allocation problem using goal programming. ElMaraghy and Ravi (1992) reviewed some applications of knowledge-based simulation systems in the domain of FMS, and also discussed their potential for the development of new, powerful and intelligent simulation environments for modeling and evaluating FMS. Kimemia and Gershwin (1985) reported on an optimization problem that optimizes the routing of the parts in an FMS with the objective of maximizing the flow while keeping the average in-process inventory below a fixed level. The machines in the cell have different processing times for an operation. Jerald et al. (2003) developed a scheduling algorithm for a particular type of FMS using particle swarm optimizer for the allocation of parts. The case of a special material handling transporter in a real time environment is treated by Han and McGinnis (1989). Taghaboni and Tanchoco (1995) developed an intelligent real-time controller for free ranging AGVs. Tanchoco and Co (1994) introduced real-time control strategies for multiple-load AGVs. Pandit and Palekar (1993) presented a number of variants of a shifting bottleneck heuristic for minimizing makespan with a single vehicle. Akturk and Yilmaz (1996) proposed an algorithm to schedule vehicles and jobs in a decision making hierarchy based on the mixed integer programming. But this approach is applicable only for the problem with small number of jobs and vehicles. Umit Bilge and Gunduz Ulusoz (1995) proposed a time window approach to simultaneous scheduling machines and material handling system in an FMS. Gunduz Ulusoz et al. (1997) proposed a genetic algorithm for the simultaneous scheduling of machines and material handling devices. Karabtik and Sabuncuoglu (1993) introduced a beam search based algorithm for the simultaneous scheduling of machines and AGVs. Their assumptions that vehicles always return to the load/ unload station after transferring a load reduce the flexibility of the AGV and its influence on the schedule. Sabuncuoglu and Hommertzheim (1992) investigated the performances of machine and AGV scheduling rules against mean flow-time criterion using a simulation model. Recently, non-traditional algorithms such as Adaptive Genetic Algorithm (AGA) and Ants Colony Optimization (ACO) algorithm have been emerging as promising tools for solving optimization problems. Most of the researchers have developed algorithms for solving FMS parts scheduling and AGV scheduling separately. This work has explored the merits of AGA and ACO for solving simultaneous scheduling of both parts and AGVs in an FMS environment.

Problem Description

Type and the operations of FMS differ with its configuration. Since the generalized configuration is not possible most of the research is conformed to specific manufacturing systems. Configuration of the system along with the assumptions and the objective criteria and the problem considered in this work are presented in the following sections.

FMS Descriptions

- The FMS considered (Jerald, Asokan, Prabhaharan, & Saravanan, 2003) in this work has five Flexible Machining Cells (FMC) and its configuration is shown in the figure1.
- Each FMC consists of two to six numbers of Computer Numerical Machines (CNC) each with independent and self sufficient tool magazines, one Automatic Tool Changer (ATC) and one Automatic Pallet Changer (APC).
- Each cell is supported by one to three dedicated robots for intra cell movement of materials between operations.
- There is a loading station from where the parts are released for manufacturing in the FMS. There is an unloading station from where the finished parts are collected and conveyed to the finished storage. And one Automatic Storage and Retrieval System (AS/RS) to store the work in progress.

- The cells are connected by two identical Automated Guided Vehicles (AGVs). These AGVs perform the inter cell movements between the FMCs, the movement of loaded pallets from the loading station to any of the FMCs, the movement of finished product from any of the FMCs to the unloading station and the movement of semi finished products between the AS/RS and the FMCs.
- There is a dedicated robot for loading and unloading AGVs.

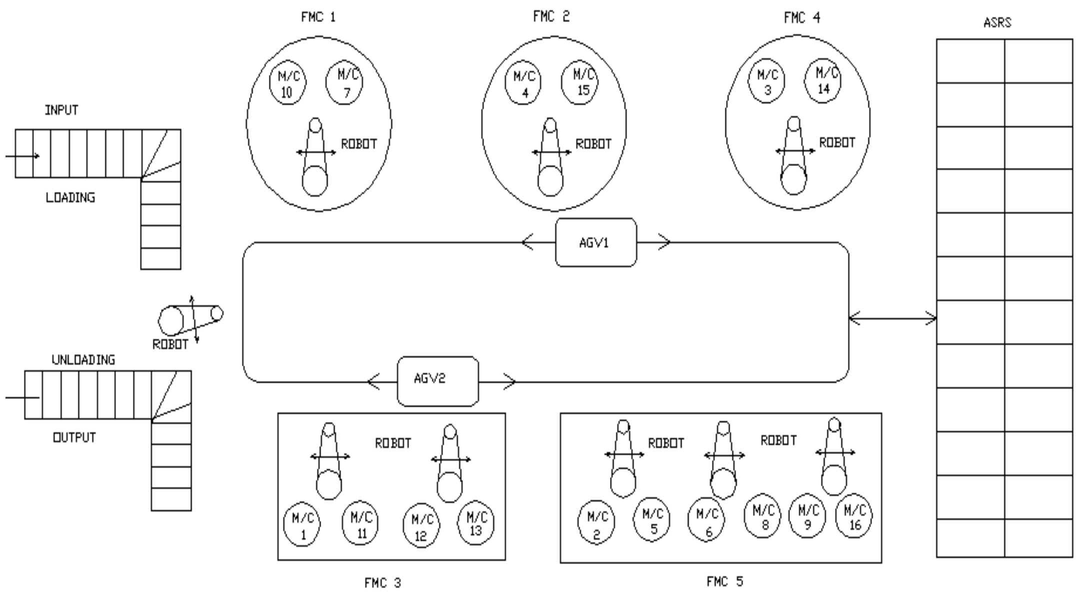

Figure1.FMS Configuration

Assumptions

The assumptions made in this work are

- Particular combination of tools in the tool magazine is used for 40 to 50 varieties of products.
- Each type/variety has a particular processing sequence batch size, due date and penalty cost for not meeting the due date.
- Each processing step has a processing time with a specific machine.
- The machine cells and part families are optimum with respect to minimum handling and backtracking.
- Random product mix generated as shown in the table1, reflects the current market demand.
- Number of AGVs is given and the AGVs are all identical in the sense that they have the same speed (5-100 m/min.) and load carrying characteristics.
- The distance between work centers are assumed to be 6metres.
- Such issues as traffic control, congestion, machine failure or downtime, scraps, rework, and vehicle dispatches for battery changer are ignored here and left as issues to be considered during real-time control.

Part Number	Processing Sequence –{Machine number & Processing time in minutes)	Due date (days)	Batch Size (numbers)	Penalty cost (Rs/units/day)
1	{6,1},{7,1},{8,1},{10,2}	17	150	1.00
2	{2,1},{6,1},{8,1},{9,2},{14,4},{16,2}	17	200	1.00
3	{8,1},{11,3},{13,4}	14	800	1.00
4	{9,4}	26	700	2.00
5	{4,5},{5,3},{15,4}	11	150	1.00
6	{6,5},{14,1}	16	700	1.00
7	{3,5},{6,3},{16,5}	26	250	2.00
8	{5,4},{6,5},{8,1}	26	850	2.00
9	{4,1},{5,5},{8,1},{11,1}	1	100	0.00
10	{2,2},{9,1},{16,4}	20	150	2.00
11	{8,4},{12,2}	1	250	1.00
12	{6,2},{8,4},{10,1}	19	1000	3.00
13	{6,1},{7,5},{10,4}	25	700	4.00
14	{4,2},{5,3},{6,2},{15,2}	22	1000	4.00
15	{5,4},{8,3}	15	700	5.00
16	{5,3}	27	750	3.00
17	{3,1},{6,4},{14,1}	20	650	4.00
18	{9,2},{16,3}	24	250	5.00
19	{4,1},{5,5},{6,2},{8,2},{15,5}	5	450	1.00
20	{8,2},{11,4}	11	50	5.00
21	{4,5},{5,5},{6,2},{8,2},{15,5}	16	850	3.00
22	{12,5}	24	200	5.00
23	{4,2},{5,1},{6,5},{8,4}	14	50	4.00
24	{8,4},{11,4},{12,5},{13,4}	7	200	5.00
25	{7,3},{10,2}	24	350	1.00
26	{10,2}	27	450	0.00
27	{8,5},{11,5},{12,4}	22	400	1.00
28	{2,1},{8,1},{9,2}	3	950	5.00
29	{4,1},{5,5}	7	700	1.00
30	{11,3},{12,5}	18	1000	1.00
31	{8,2},{10,2}	2	800	2.00
32	{2,3},{6,4},{9,3}	15	800	1.00
33	{5,4},{6,5},{15,3}	27	500	4.00
34	{3,2},{6,2}	12	300	4.00
35	{3,4},{14,1}	9	900	2.00
36	{3,2}	20	700	2.00
37	{1,5},{2,2},{6,3},{8,3},{9,2},{16,4}	22	250	4.00
38	{2,4},{8,3},{9,2},{16,5}	8	50	1.00
39	{6,5},{10,5}	9	500	1.00
40	{2,2},{6,4},{9,4}	7	250	5.00.
41	{5,1},{8,2},{15,1}	22	800	4.00
42	{2,5},{6,4},{9,3},{16,1}	19	400	2.00
43	{1,3},{5,2},{6,2},{8,2},{15,3}	15	550	3.00

Table1.Machining Sequence, Time, Due date, Batch size and Penalty Details.

Objective Function

Production systems are designed essentially to meet demand efficiently. Productivity indicates the efficiency of the system effectiveness and depends on many aspects such as machine utilization, tardiness, in-process inventory and manufacturing lead-time. One or more of the parameters are used to measure the efficiency of the system. The scheduling objective criterion is selected based on those performance parameters. The performance parameter is decided based upon the business environment. The utilization function, which leads to increased machine usage (the complement of idle time), is widely adopted, where the capital cost is high. Considering this aspect, the utilization of machine is considered as a measure of system performance. If the jobs are properly sequenced, then the idle time of the machining center can be minimized and their utilization can be maximized. Minimizing the penalty cost for not meeting the delivery date is also considered in this work. Two contradictory objectives are aimed to achieve simultaneously by the scheduling mechanism. Ant colony optimization is used in this to solve the above problem. The objective function, which can be defined mathematically for the problem, which was undertaken, is as follows:

$$\textbf{Minimise COF} = (W1 \times \{Xp \div MPP\}) + (W2 \times \{Xq \div TE\})$$

Where

W_1 = Weightage factor for customer satisfaction

Xp = Total penalty cost incurred

$X_p = \sum_i (\{CTi - DDi\} \times UPCi \times BSi)$

i = Job number

CTi = Processing time of job i + Transportation time of AGV

DDi = Due Date for job i

UPCi = Unit Penalty Cost for job i

BSi = Batch Size of job i

MPP = Maximum Permissible Penalty

W_2 = Weightage factor for machine utilization

Xq = Total machine down time

$Xq = \sum_j (MD_j)$

j = Machine number

$MD_j = (TE - \sum_i PT_{ji})$

TE = Total Elapsed time

PTji = Processing Time of i^{th} job with j^{th} machine

In the experiment conducted equal weightages are given W_1=0.5 and W_2=0.5. However different ratios can be applied to them according to the demand of business situation.

Proposed Methodology 1: Adaptive Genetic Algorithm

Despite the success of applying genetic algorithm to solve numerous real-life problems, the identification of the correct settings of genetic parameters for the problems is not a simple task. Indeed, the performance of the genetic search process may be severely hampered if poor settings are used. In order to ameliorate this shortcoming, a new scheme is proposed of setting the genetic parameters during the course of the search process. This scheme involves some rules to adjust adaptively the crossover and mutation rates according to the performance of the genetic operators. It increases the probability of the occurrence of the genetic operator if it consistently produces a better offspring during the recombination process; however, it also reduces the probability of the occurrence of the genetic operator if it always produces a poorer offspring. This scheme is based on the fact that it encourages the well-performing operators to produce more offspring, while also reducing the chance for poorly performing operators to destroy the potential individuals during the recombination process. The proposed scheme can adaptively regulate the balance between the exploration and exploitation of the solution space by adjusting the crossover and mutation rates during the genetic search process. In this connection, the proposed scheme can provide a better and faster means to identify the global optimal solution.

Algorithm for Adaptive Genetic Approach

Step1: Randomly generate an initial population of individuals by using a symbolic representation scheme. Evaluate the fitness of the individuals by determining the combined objective function of the candidate solutions represented by them.

Step2: Select a pair of individuals from the current population by using a rank order selection method.

Step 3: The selected individuals are recombined to generate a pair of offspring by using the single point crossover according to the crossover rates. Evaluate the fitness of the two offspring by determining the combined objective function of the candidate solutions that they represented.

Step4: Record the percentage of improvement, or the percentage of degradation, on their fitness values owing to the crossover operation.

Step 5: Process the traditional symbolic mutation of the two offspring and evaluate their fitness by determining the combined objective function of the candidate solutions represented by them.

Step 6: Record the percentage of improvement, or the percentage of degradation, of their fitness values as a result of the mutation operation.

Step 7: Allocate the resulting individuals into a new population pool. If the population size is not reached, return to step 2.

Step 8: Adjust the crossover and mutation rates in accordance with the following rules.

1. If the percentage of improvement in fitness values of the majority of the offspring exceeds the fitness values of their respective parents by 10% or more, the probability of the occurrence of the genetic operator will be increased by a step of 0.05 if the genetic operator is crossover, or by a step of 0.005 if the genetic operator is mutation.

2. If the percentage of degradation on fitness values of the majority of the offspring exceeds the fitness values of their respective parents by 10% or more, the probability of the occurrence of the genetic operator will be decreased by a step of 0.05 if the genetic operator is crossover, or by a step of 0.005 if the genetic operator is mutation.

3. If the percentage of improvement/degradation on fitness values of the majority of the offspring falls within ±10% of the fitness values of their respective parents, the probability of the occurrence of the genetic operator will be unchanged.

4. In the case of 1 or 2, the adjusted probability should not exceed the domain of 0.5 to 1.0 if the genetic operator is crossover, and the domain of 0.00 to 0.10 if the genetic operator is mutation.

Step 9: Check the stopping condition. Terminate the genetic search process and adopt the best candidate solution over time as the final solution if the stopping condition is satisfied. Otherwise, proceed to the next generation with the old population to be replaced by the new population, and return to step 2.

Adaptive Genetic Algorithm Parameters

Population size (n) = 20 samples
Initial Crossover probability (Pc) = 0.6
Initial Mutation probability (Pm) = 0.05
Termination criteria =100 generations

Proposed Methodology 2: Ants Colony Optimization

Ants Colony Optimization (ACO) is a metaheuristic to tackle a hard combinatorial optimization problem that was first proposed in the early 1990s M. Dorigo, V.Maniezzo, and A.Colorni (1996). Fascinated by the ability of the almost blind ants to establish the shortest route from their nests to the food source and back, researchers found out that these ants secrete a substance called 'pheromone' and use its trails as a medium for communicating information among each other. Real ants are capable of finding the shortest path from a food source to the nest without using visual clues. Also, they are capable of adapting to changes in the environment, for example finding a new shortest path once the old one is no longer feasible due to a new obstacle. It is well known that the primary means for ants to form and maintain the line is a pheromone trail. Ants deposit a certain amount of pheromone while walking, and each ant probabilistically prefers to follow a direction rich in pheromone. This elementary behavior of real ants can be used to explain how they can find the shortest path that reconnects a broken line after the sudden appearance of an unexpected obstacle in the initial path. Once the obstacle has appeared, ants, which are just in front of the obstacle, cannot continue to follow the pheromone trail in the straight line. In this situation some ants choose to turn right and the other half to turn left.

It is interesting to note that those ants which choose, by chance, the shorter path around the obstacle will more rapidly reconstitute the interrupted pheromone trail compared to those which choose the longer path. Thus, the shorter path will receive a greater amount of pheromone per time unit and in turn a larger number of ants will choose the shorter path. Due to this positive feedback (autocatalytic) process, all the ants will rapidly choose the shorter path). The most interesting aspect of this autocatalytic process is that finding the shortest path around the obstacle seems to be an emergent property of the interaction between the obstacle shape and ants distributed behavior.

Although all ants move at approximately the same speed and deposit a pheromone trail at approximately the same rate, it is a fact that it takes longer to contour obstacles on their longer side than on their shorter side which makes the pheromone trail accumulate quicker on the shorter side. It is the ant's preference for higher pheromone trail levels, which makes this accumulation still quicker on the shorter path. A similar process can be put to work in a simulated world inhabited by artificial ants to solve a hard combinatorial optimization problem.

Algorithm for Ants Colony Approach

Step1: Fix the evaporation rate and no of runs ()
Step2: While (no of runs is less than required ()
Step3: Initialize pheromone values ()
Step4: Call random no generation function ()
Step5: Generate group of ants with different paths (sequences)
Step6: Call the function for calculating cof ()
Step7: Sort the cof values in ascending order ()
Step8: For best routes update pheromone level ()
Step9: Repeat 4,5,6,7 &8 till obtaining required no of runs ()
Step10: Print the best routes and the cof values ()
Step11: Change evaporation rate and no of runs for next trial ()

Results and Discussion

The designed scheduling procedure with AGA and ACO, software is developed in the "C" language to conduct experiments. While conducting trials it is found that the procedure is able to achieve the objective well before one of the termination criteria of the AGA mechanism is met. This nearer to optimal schedule for the FMS, using AGA is compared with sequence obtained by ACO and AGA gives superior results than ACO. The speed of AGV is also considered in this work.

Sl.No	Scheduling Algorithm	Job Sequence	AGV Sequence	COF
1	Ants Colony Algorithm	28-20–23–38-1-9-26- 22-10-34-18-36-11-25-5-16-2-40-4-31-41-7-24-17-6-29-35-37-15-39-42-27-33-3-43- 19-12-13-30-32-8-14-21	2-1-2-1-2-1-1-2-2-1-1-2-1-2-1-1-2-1-1-1-2-1-2-1-2-1-2-1-1-1-2-2-2-2-1-1-1-1-1-1-2-1-2	0.343096
2	Adaptive Genetic Algorithm	37-11-3-13-29-6-39-10-22-28-18-38-36-34-21-1-31-2-5-33-24-7-35-40-23-43-17-15-20-14-32-41-26-9-42-27-12-30-16-4-19-25-8	1-2-1-1-2-2-1-2-2-1-1-2-1-2-2-1-2-2-1-1 -1 -1-2-1-1-2-2- 2-2-2-2-2-1-1-1-2-2-2-2-2-1-2-1	0.319741

Table2.Results of ACO and AGA

Conclusion

In this paper, Adaptive Genetic algorithm and Ants Colony Optimization algorithm for scheduling parts and AGVs simultaneously for a flexible manufacturing system have been developed. The developed algorithms are used to optimize two contradictive objectives i.e. total machine idle time and total penalty cost, simultaneously. The speed of AGVs is also examined in this work. The Adaptive Genetic approach gives more optimal COF value than Ants Colony Optimization and found to be superior. These approaches can be suitably modified to any kind of FMS setup and can be applied for optimizing different objectives.

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