A

Dissertation Report

On

An Empirical Study and Model Assessment of Scheduling Performance Metrics in Automobile Industries

For partial fulfillment of the degree of

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Submitted by:

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CERTIFICATE

This is to certify that the work presented in this dissertation entitled **"An Empirical Study and Model Assessment of Scheduling Performance Metrics in Automobile Industries"** in partial fulfilment of requirement for the award of degree of MASTER OF ENGINEERING in Production Engineering in the Mechanical Engineering Department, THAPAR UNIVERSITY, PATIALA is an authentic record of initial work carried out by me under the supervision and guidance of **Mr. Supreet Bhullar**, Associate Professor, Mechanical Engineering Department, Thapar University, Patiala. The matter embodied in this dissertation report has not been submitted anywhere else for the award of any other degree.

Dated: 14|07|2016

(Puneet Yadav)

This is to certify that above declaration made by the student concerned is correct to the best of my knowledge and belief.

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ABSTRACT

In today’s competitive business environment the planning and scheduling significantly influence the organizational performance, hence it is a quintessential aspect of the entire production system, though there is a limited literature on how an organization should organize and assess the planning process. The purpose of this thesis is to identify the factors on which scheduling performance can be measured in the automobile industries in the Northern India specifically. We extend planning and scheduling theory with a categorization of scheduling performance criteria, based on survey research design. In this research data from various automobile manufacturing industries in the northern India has been collected with the help of a questionnaire and analyzed using Statistical Package for the Social Sciences (SPSS) and Partial least square (PLS) has been used to develop the measurement and structural model for the study. Separate data have been collected planners and managers, hence separate models have also been prepared. Particularly, the results show that the scheduling process and product criteria have been significantly affecting the scheduling performance. The results revealed that executional uncertainty negatively affects the influential factors for both planner and the manager, while environmental uncertainty has a positive impact according to the manager and negative impact according to the planners and, hence study reports lack of coherence amongst the opinion of planner and manager. Therefore this research theoretically contributes to scheduling and performance measurement literature and practically supports managers and planner in developing scheduling performance measurement systems.

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Chapter I

Introduction

1.1 General

Today's industrial environment has become extremely competitive. Manufacturing establishments have started identifying the importance of manufacturing strategy in their businesses. Firms are often facing pressures to improve the functions within the production system, manage demand variability and be price competitive. In order to fulfill a vast number of challenges, firms usually find themselves in a situation with critical shortages of some products and surplus inventories in case of others. It raises the problem of finding a proper equilibrium between cost cutting and maintaining customer responsiveness. Organizations are facing internal pressures to increase the profit of the organization through enhancements in production processes and reduction in operating costs. Therefore, efficient production planning and scheduling of material could be seen as the stepping stone towards meeting the challenges raised above. Ever since their introduction, the computer-based production planning and scheduling software, have eased the processes in manufacturing companies. The whole process of developing an information system based software system started with the evolution of Material requirement planning (MRP) systems in the 1970s, later with the introduction of manufacturing resource planning (MRPII) systems in the 1980s and then through enterprise resource planning (ERP) systems in the 1990s, ending in the most recent and innovative software, like advanced planning and scheduling (APS) systems Scheduling being an integral part of manufacturing system, it greatly affects the overall performance of the system. As the performance of scheduling is very important, the question arises here is, how to measure the performance of scheduling and what criteria should be used to evaluate the performance of the schedule in the industry.

The main motivation for this research is to investigate the criteria for the measurement of performance of production planning and scheduling in manufacturing industries. The rest of this chapter is structured as follows. The next section (Section 1.2) explains the importance of scheduling and performance measurement whereas in last section the complete structure of the study has been explained.

1.2 Importance of scheduling and performance measurement

Scheduling is a process that brings all the activities within the production to their fulfillment. Scheduling could be seen as the key link between the planning and the execution phase of operation in any manufacturing industry and requires to be executed smoothly taking all constraints within the production system into consideration. Without effective scheduling, the overall planning system will not find its true potential. Though it is an important aspect of the manufacturing system, scheduling is itself a process. It requires the collection of data from sources such as data related forecasting of demand or customer order, resource availability from the sales and operations plan. The schedule has to be coordinated with the employees and suppliers to make sure that all the constraints are satisfied. Scheduling is an essential phenomenon irrespective of the industry. The scheduling includes a huge amount of details and affects all most every process in the company, such as fulfillment of order depends on, delivering the goods and services to the customers on time, which is the outcome of good planning and scheduling system. In addition to this scheduling also plays a very important role, when customers place an order, the scheduling process determines when they can receive their shipments. Therefore, it becomes very easy to understand that good performance of production scheduling is quintessential for a manufacturing system.

Given the development of computer based scheduling systems and software, firms have transformed the scheduling process into a competitive weapon and has been very helpful in coping with the complexity of the scheduling process, thus useful in improving scheduling performance. There are number factors that affect the scheduling performance and uncertainty being the most challenging amongst them. Since the improvement of scheduling performance is vital to achieving therefore, it is very important to know measures how scheduling performance can be measured. There is different ways firm's measure scheduling performance, which varies according to their functioning, size etc. The perspective of a manager working on the schedule should also be taken in to consideration. The next section explains how exploratory research work of identifying the criteria for measuring the scheduling performance has been conducted.

1.3 Structure of research

Scheduling performance has become an important aspect of firms planning system. An empirical research for identifying the criteria for measuring the scheduling performance has been conducted. The first step towards the research has been to conduct a literature review, this has been done to identify criteria on which scheduling performance can be measured. Once the criteria and their measures have been recognized, a questionnaire was prepared. The questionnaire was strategically designed on 5 point Likert scale. As the performance of a schedule depends on the manager and planner both so it was decided get the response from the schedulers (one who prepares the schedule) and managers (one who uses the schedule) of automobile companies across the north India. The questionnaire was first sent to 5 firms for pre testing and validation purpose. The suggestions from the respondents were reviewed and inculcated into the questionnaire, so as the get the final questionnaire. The revised questionnaire was sent to 60 number of firms through several means of communication, timely remainders were also sent so as to get the responses on time. The data received, was accurately entered into SPSS and missing values were replaced. As separate responses were received from the scheduler/planner and the manager, therefore distinct data file was prepared for the manager and the planner. The data regarding the managers and planners was then statistically analyzed in SPSS.

There is a complex relationship between the different scheduling performance criteria, therefore to judge the relationship amongst them another tool called Partial Least Square- Structural Equation Modeling (PLS SEM) has been used. Using this tool, distinct measurement model was assessed and composite reliability, Cronbach's alpha, Average Variance Extracted (AVE), Fornell and Larcker discriminant validity criterion were evaluated to check the validity and reliability of the measurement model for the planner and the manager on the metrics identified. The structural model was also assessed to check the relationship in the model, subsequently, blindfolding and Importance-performance map analysis (IPMA) were assessed to find the predictive accuracy and important performance relationship respectively. The results and their discussion are drawn from these assessments have been explained in the section IV and V respectively.

Chapter II

Literature Review

This chapter reviews the previous studies on production planning and scheduling performance in discrete parts of manufacturing industries. There has been a renewed interest in the application of mathematical programming to address production planning and scheduling decisions (Graves et al., 1993).However, in recent time significant research has been done to address the scheduling performance. The interest has been mainly due to the increased demand for efficient production schedule in the industry to support the production system. For this reason, managers have been actively seeking metrics to improve the production scheduling performance. Thus some previous models developed and applied in the industry has been reviewed.

Scheduling is an integral part of production system which not only affects the productivity but also other important factors such as product quality, market share etc. Bagsaw (2014) conducted a survey of Nigerian manufacturing firms to collect data using random sampling. The paper developed appropriate questions and hypotheses related; order scheduling, operations scheduling and master production scheduling as the measure of planning and scheduling to evaluate the production quality, market share methods productivity of the companies. The results of the study revealed that master production scheduling, operations scheduling, and order scheduling have more influence on productivity and market share than on product quality. The results also indicated that uncertainty in demand has a moderating effect on the performance production planning and scheduling of the manufacturing firms. In recent times significant rise has been observed in the research of performance measurement (Neely 1999; Melnyk et al. 2004; Evans 2004; Lehtinen and Ahola 2010). Evans (2004) described the importance appropriate measure and approaches taken in measuring the results in designing an effective performance measurement system. The paper also raised a vital question that despite its importance, several organizations fail to address this area effectively. The paper reports empirical results, received from an on-line survey, on the relative importance and types of performance measurements and analysis approaches used by manufacturing and service sector organizations and also by the nonprofit organizations. The results show that organizations with more advanced performance measurement systems reported better results in terms of customer, financial, and market performance. Lohman (2004) described the process and the results of an initiative to significantly improve the supply chain performance measurement capabilities of a company. The paper addressed the performance measurement using local performance indicators, which were incorporated at different levels to assist manager to work on different platforms. The study is based on the case study carried out at the European operational department of Nike, a worldwide sportswear manufacturer. The results of the study presented a model, which basically is a scorecard prepared according to the on the needs of the company. Neely et al. (2005) conducted the research to find the importance of performance measurement. An exhaustive review of the literature has been conducted to emphasize on the process of performance measurement system design rather than the explanation of various methods. The paper also underlines the interest towards the importance of performance measurement. As the focus of the present research being the production scheduling, so the literature reviews illustrating the development of scheduling methods for problems in production scheduling have been explained. Allahverdi et al. (2008) provided a literature review of scheduling models with setup times. Several independently developed techniques have been identified and compared the present models. The scheduling problems have been classified as batching and non-batching type, and also as sequence-independent and sequence-dependent setup times. The paper further categorized the literature according to shop environments, including single machine, parallel machines, flow shop, no-wait flow shop, flexible flow shop, job shop, open shop etc. Hoogeveen (2005) emphasized mainly on multi-criteria scheduling focusing specially in the field of earliness-tardiness scheduling, scheduling with manageable processing times and simultaneous approximation. Potts and Kovalyov (2000) presented a review on integrating scheduling with batching and argued how batching could reduce the complexity of scheduling process which in turn improved the scheduling performance. Hsu (2006) proposed a new model for scheduling performance measurement which included important scheduling processes and their allowable floats. According to this model, an algorithm has been developed to derive total float and free float for every operation to be carried out on a schedule. With the help of these floats criticality of each operation on the shop floor could be assessed, so that each operation could be executed with an appropriate control action. The paper also argued that the issue of rescheduling strategy should be considered as the last control strategy. It was suggested that before applying the rescheduling, shop floor supervisors should be capable of reducing the disparity in each operation to reach the original scheduling objective value. In a recent research development Xu et al. (2015) proposed an intelligent method based on a modified league championship algorithm to project the performance of production scheduling. This algorithm overcomes the drawbacks of original algorithm in a match schedule. Though, these research papers mentioned above focused on different aspects improving the performance of production scheduling but still there is a scarcity of literature on criteria's or metrics on which production scheduling can be measured. Snoo et al. (2011) through an empirical research proposed the criteria for the firms to assess scheduling performance. The study was conducted in three stages sequentially, in the first two stages open ended questions have been asked from the respondents of industries. Based on the results of the studies in first two stages a questionnaire has been prepared for the third stage of the study, which included a survey of 125 different types of companies. Thus study proposed four scheduling criteria namely criteria focused on scheduling product, criteria focused on scheduling process, indirect scheduling performance criteria, and influencing factors based on their descriptive survey study. The importance of uncertainty in the performance of the schedule has also been explained. The authors described mainly two types of uncertainties, executional and environmental uncertainty which affects the performance of schedule. As uncertainty is one of the most important aspects of the scheduling, as these are the unforeseen disruptions in the production system. According to Aytug et al. (2005), uncertainty can be classified in a various way and uncertainty is one dimension for the execution of the schedule. Field et al. (2006) empirically studied the relationship between responses to operational uncertainty and process performance. This study mainly stresses on the question of what best can be done by managers to address operational uncertainty effectively and also the steps required to be taken in order to mitigate the undesirable effects of uncertainty. The paper suggested a significant relationship between process improvement-an uncertainty reduction approach and service quality, as well as a significant positive association between controlling uncertainty and process performance, with internal control systems, cross training, and effective use of information technology to enhance overall performance and service quality. Rasconi (2008) proposed a new technique to execute a comparative evaluation of different approaches to address the problem of uncertainty in scheduling. The analysis focuses on evaluating the influence of both the proactive (off-line) and reactive (on-line) scheduling efforts on the robustness of the baseline solutions, against measurable disrupting factors, through reproducible experiments. The results revealed the important aspects of scheduling, which are extremely useful and this would have remained undetected through static metric evaluations. Graves (2011) reviewed and discussed the way uncertainty was handled in production planning and argued the role of tactical decisions in the proper handling of uncertainty in production planning. The paper also explains that ongoing planning systems lack adequate decision support for this types of strategic decisions. The research mainly focuses on the production planning and scheduling practices followed in different types of industries with a goal to provide a framework and set of observations on existing practice and looking for new ways to improve the system. Wojakowski and Warzolek (2014) conducted a research study to answer the question: how the issue of production uncertainty can be managed to take into account the scheduling problem. The results of the paper revealed that four approaches, namely, reactive scheduling, proactive scheduling, predictive-reactive scheduling and robust predictive-reactive scheduling approach have been developed and fundamentally exploited in scheduling problem regarding production uncertainty. Paper also observed that research attention on the issue of planning scheduling with uncertainty is still growing because of it being a practical problem occurring in the production systems. In a review of literature spanning over a decade, Sagawa and Nagano (2015) stressed on the need for research on information quality in the manufacturing industry context while suggesting better coping with uncertainty could lead to better performance and underlines much need of research on information quality in a manufacturing context. The paper also proposed a conceptual framework to classify the reviewed work. Bstieler (2005) presented an empirical study, examining the effect of environmental uncertainty on new product development. The study has the sample size of 182 projects from Canada and Australia. The findings of the study show that environmental uncertainty in the Canadian industries neither directly impacts time efficiency, nor does it have any moderating effect. In contrast, the results of the Australian study suggest that environmental uncertainty directly impacts time efficiency. Chu et al. (2015) proposed a technique for integrating planning and scheduling problems under uncertainties. The paper framed a bi-level program. The planning issues have been answered at the top level, while the scheduling problems in the planning periods are solved under uncertainties in the bottom level. Croci and Pozzetti (2000) highlighted the importance of setting up Optimized Production Technology (OPT) management system in order to attain the desired performances in terms of both system efficiency as well as system effectiveness. This was examined through a case study in a leading producer of high quality acetate yarns for the textile industry. An experimental design and statistical analysis acknowledged the impact of single OPT management constraints. Bowen et al. (2014) examined the consequences of uncertain environments on strategy and strategic planning and ways to decrease uncertainty. The study reported that scenario planning has been a common approach but needs to be adapted depending on the level of uncertainty in the environment. Another approach of pseudo planning has been proposed but this does not provide a solution to uncertainty in environments and thus does not lead to a tangible competitive advantage. Using a web-based survey Pujawan & Smart (2012) captured the opinions of experts working in the planning and scheduling area in manufacturing companies about schedule instability, thereby identifying factors that affected the perceived level of instability experienced by the industry. The results indicated that schedule instability significantly affects the relationship between buyers and suppliers. At times there are issues in implementing the scheduling systems, explained by Carvalho et al. (2014) while addressing the issues related to the implementation of the scheduling system. A large two-wheeler company, with an unfamiliar degree of vertical integration. The main feature of this action research project was executions of 24 simulation-based production scheduling solution in a motor cycle industry have carried out. There are also certain basic factors which affect scheduling as described by Berglunda and Karltun (2007) in their research how the production-scheduling processes is influenced by human, technological, and organizational aspects, through a case study in four companies in Sweden. The study also provides the comprehensive comparison of human, technological and organizational factors on scheduling and concludes that they are strongly interlinked to scheduling.

Chapter III

Research Design

3.1 Introduction

This chapter includes the overall design adopted for study and the methodology adopted for carrying out the present research work. It contains the summary of the work done and provides details regarding the processes followed, tools and techniques used in the dissertation work.

3.2 Research Methodology

The study has been carried out with the objective of investigating the scheduling performance criteria in automobile industries in northern India. For proper functioning an organization it is important to measure and manage scheduling performance and thus appropriate performance criteria or metrics are needed to measure the scheduling performance. The study endeavors to explore all the critical aspects of scheduling performance criteria in practice in the industry. The methodology used for the research has been explained below in Fig. 3.1.

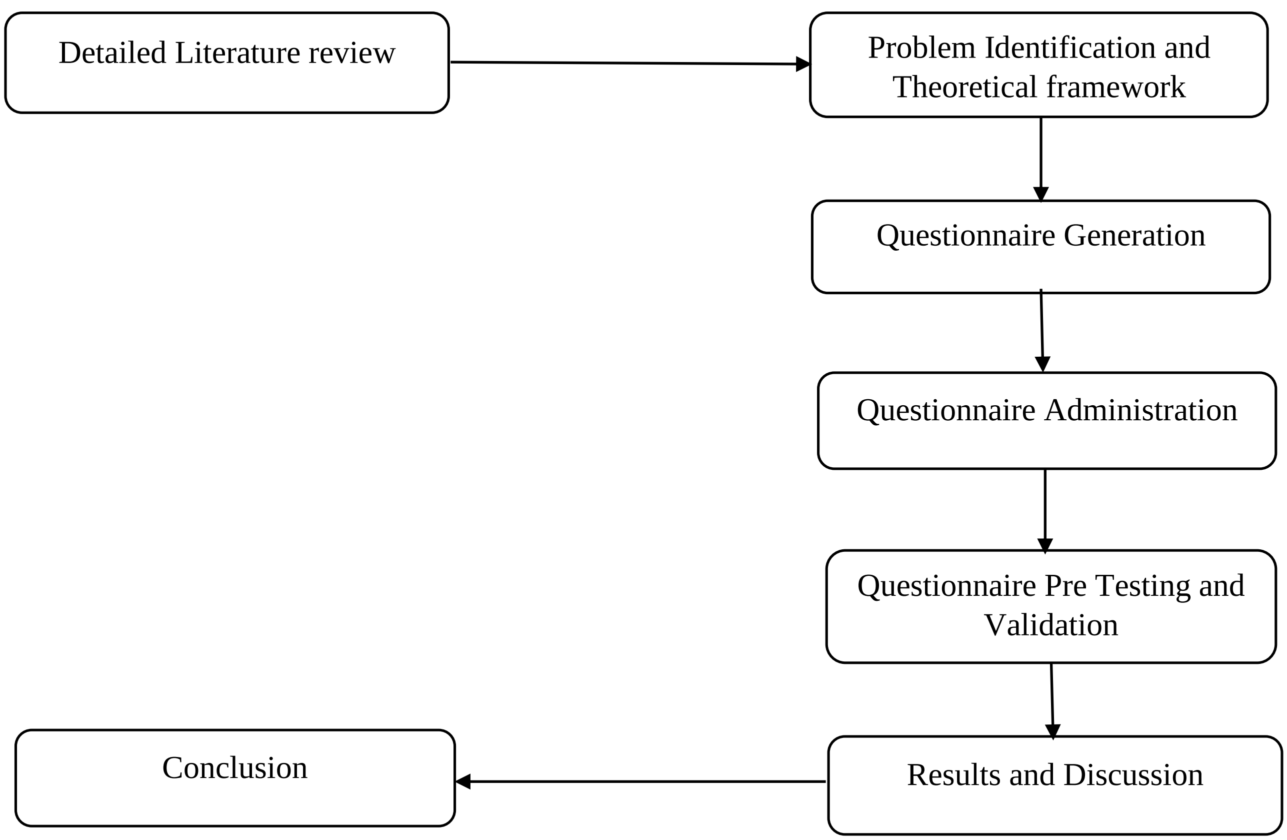


Figure: 3.1 Methodology for the Study

3.2.1 Design of Questionnaire

The questionnaire design can be broadly divided into three parts:

1. Determining the questions to be asked.
2. Measurement scale and language of the questionnaire.
3. Design of question sequence and overall questionnaire layout.

The points are now being explained below:

3.2.1.1 Determining the questions to be asked

This is the first and the most important part of the questionnaire i.e. to determine the questions to be asked in the questionnaire. This detailed questionnaire was needed to seek information on various production planning and scheduling performance related issues from industry. As scheduling performance is a complex parameter to judge, therefore extensive literature review has been carried out for finding the effective criteria for measuring scheduling performance (Snoo et al., 2011; Allahverdi et al. 2008; Hoogeveen 2005). Subsequently, by exploring the literature it was found that there are several factors which affect scheduling performance and these factors can be broadly classified on four criteria:

- **Criteria focused on scheduling of product**

The first metric identified for measuring scheduling performance is scheduling of product. There are several measures which affect the scheduling of product (Snoo et al., 2011). There were 11 measures identified focusing scheduling of product. This included the schedule and other relevant information related to the schedule. These eleven measures have been framed into question form, corresponding to the criteria shown in Table 3.1.

Criteria:	**Question focus:**
Criteria focused on Scheduling of product	Correct processing times of the schedule
	Correct production routings for the scheduling
	Orders are delivered on time
	Number of setup times are minimized
	Number of waiting times are minimized
	Overtime is minimized

	Schedule is easily adaptable
	Scheduling shifts fit labor laws
	Resource utilization rates are realized (No Shortages or No Surpluses)
	Schedule remains within financial budgets
	Schedule provide information about choices made by all the stakeholders

Table 3.1 Criteria focused on Scheduling of product

- ## Criteria focused on scheduling of process

The second metric identified for measuring scheduling performance is scheduling of process. The scheduling process comprises the set of activities that are used to develop, communicate and adjust the schedule and changes in the schedule. There were seven measures found to affect the scheduling process (Snoo et al., 2011). Hence seven questions have been raised to measure this criteria.

Criteria:	Question focus:
Criteria focused on scheduling of process	The scheduler releases the plans in time.
	The scheduler accommodates the rush order requests promptly.
	The scheduler is easily accessible to renegotiate schedule constraints (example - due dates, routing, rush order)
	The scheduler collaborates with Production, Stores, and Marketing for finalizing the schedule.
	The scheduler balances the stakeholder’s interests in finalizing the schedule.
	The scheduler communicates the finalized schedule to the stakeholders.
	The scheduler does not micro manage operations on the shop floor.

Table 3.2 Criteria focused on Scheduling of process

- **Indirect Measures affecting Scheduling performance**

Indirect measures section mainly consist of some important factors such as customer satisfaction, complaints and feedback from the users of the schedule as it was found that some managers and schedulers recognizing these measures as metric for measuring the scheduling performance. Six questions regarding these measures (Snoo et al., 2011) has been identified to be asked in the industry, these are depicted below in Table 3.3.

Criteria:	**Question focus:**
Indirect Measures affecting Scheduling performance.	Increased Satisfaction of clients
	Reduced absenteeism rates dues to employee satisfaction with the schedules
	Fewer complaints from employees
	Fewer production shifts in overtime mode
	Fewer inventory shortages or surpluses
	Fewer changes in the delivery dates of consignments

Table 3.3 Indirect Measures affecting Scheduling performance

- **Influential factors of scheduling performance**

Along with the criteria actually measuring the scheduling performance, six factors (Snoo et al., 2011) were deduced which influence the scheduling performance and has been explained below in table 3.4.

Criteria:	Question focus:
Influential factors of Scheduling performance	Correct estimation of job processing time
	Reduced number of sources of information for making schedule
	Fixing ownership of the scheduling process in the department
	Updated data on production standards is available
	Increased use of automated scheduling system(computer-based scheduling)
	Increased scheduler's knowledge and skill

Table 3.4 Influential factors of Scheduling performance

- ## Uncertainty in scheduling

The above criteria present the measures for the scheduling performance but one key factor which comprehensively affects the production schedule is uncertainty, it is the prime reason for problems in scheduling and most of the times uncertainty is the major reason for the rescheduling off the production plan. Therefore, significant emphasis has been on the uncertainty for proper planning and scheduling. The uncertainty can be classified as executional uncertainty (uncertainty concerned with execution scheduling process which avoids the execution schedule as intended) and environmental uncertainty (concerns with varying information about what has to be scheduled, and the constraints to be taken into consideration (Snoo et al., 2011).

It was decided to prepare questions for both the uncertainty separately so that it could be appropriately understood from the industries point of view. The questions prepared for both types of uncertainty is shown in the Table 3.5 and 3.6.

Criteria:	Question focus:
Executional uncertainty in scheduling	Execution of schedule has been delayed frequently
	Schedule has not been executed as intended
	Increase in slack time in schedule observed frequently
	Rate of feedback to the scheduler from manager is high
	Requests for rescheduling received frequently

Table 3.5 Executional uncertainty in scheduling

Criteria:	Question focus:
Environmental uncertainty in scheduling	Frequency of rush orders observed
	Rate of new information being conveyed to the scheduler(once the schedule has been released) is high
	Frequent delay in shipments from suppliers observed
	High frequency in transit delay observed

Table 3.6 Environmental uncertainty in scheduling

This concludes the first part of the questionnaire generation, which was started with an objective to determine the question to be asked in the questionnaire.

3.2.1.2 Measurement scale and Language of the questionnaire

It was decided to prepare a closed ended questions for the questionnaire and a measurement scale which would be best suited for this survey research. There are number of options available regarding the format of the scale to be used for the survey. The scale should mainly be chosen, based on the type of questions asked in the survey. There are different types of scales available which can be used for obtaining the responses, but 5-point Likert scale has been chosen, which is explained below.

Likert Scale

The Likert Scale is an ordinal scale used for measuring views, beliefs, and attitudes. It is assumed to be linear in a range from strongly agree to strongly disagree. In this type of scale, a multiple choice format is provided to the responded to mark the degree of agreement or degree disagreement The main advantage of Likert Scale is that responses can be are easily quantified and mathematical analysis can be easily performed as the responses are subjective. Another advantage of this scale is that it keeps the interest of respondents alive because it does not force the participant to be rigid on a particular topic, rather allows them to respond on 5 point scale and this makes the whole process of survey easier to the respondent. Also, the responses presented comprises the positive, neutral and negative feelings of the respondent. The surveys conducted using Likert scale is the fast, efficient and inexpensive approach for the collection of data. These scales are highly flexible as these can be sent out through the mail, or given though person visits. It can be 5-point, 7-point or 9 point scale within these the most appropriate was to be chosen (Kothari 2004).

- 5-point scales: Correct, and mostly used.
- 7-point scales: Correct, and more useful for skewed data.
- 9-point scales: Skewed, fatiguing, and should be avoided.

So due to above advantages, it was decided to choose the 5 point Likert scale as the measurement scale for the questionnaire.

The language of the questionnaire is also a very important aspect of the questionnaire because it is very key for the respondents to understand the questions properly in order to respond easily, so it was tried to keep the language as simple as possible. To remove any confusion, it was tried to keep the question unambiguous and concise. The question, raising double meaning and negative meaning were avoided. It was also tried include definitions where ever necessary for the convenience of the respondents.

3.2.1.3 Design of question sequence and overall questionnaire layout

The sequence of the questionnaire was planned strategically, the questions were placed sequentially to raise the interest of the respondent as the whole research was relying on the respondent to complete the questionnaire. Efforts were made tried to keep the flow throughout the questionnaire logical and very simple, i.e. complex branching was avoided. The questionnaire was divided into nine sections. Section A seeks general information on industrial organizations like organization type, industry sector, department, designation etc. Section B to section H seeks information on the scheduling performance related issues faced in the industry as explained in the section 3.2.1.1. The section B, C, D, E, include the questions related to scheduling product, scheduling process, indirect measure and influential factors respectively. The section F, G, H are related to uncertainty in planning and scheduling. The last section of the questionnaire i.e. section I includes the personal information about the manager or scheduler, who is filling the questionnaire.

The layout of the questionnaire is also an important aspect of questionnaire design. The first page starts with the introductory letter about the research. It also included the contact details, in case anyone requires some type of assistance regarding the questionnaire. Then the instructions for filling the questionnaire were explained with the help of an example, so as to avoid any inconvenience caused to the respondent while filling the questionnaire. It was decided to keep text layout as portrait and the proper font was used. Bold and italics were also used where ever necessary. This completes the design of the questionnaire, appendix A provides the actual questionnaire.

3.2.2 Confidentiality and Ethics

As it is very important to allow privacy to the respondents hence it was decided not ask anything which may offend the respondents. Apart from the things which were essential nothing else was asked. The respondents were even not compelled to reveal their identity or anything regarding there company if they were not comfortable.

3.2.3 Questionnaire Pre-Testing and validation

To ensure the quality of the questions pertaining to the automobile manufacturing industries, the questionnaire has been pre-tested in the industry. The aim here has been to detect any errors in the questionnaire and to correct these errors before conducting the main survey. Pre-testing involved 12 respondents, which included 6 planners and 6 production managers. Respondents were asked to scrutinize the questionnaire on the basis of the planning and scheduling operations they carry out in their company, so as to capture realistic data. The suggestions from the senior executives, managers from industries, indicated issues related to the length of the questionnaire. These suggestions were used to revise questionnaire. The survey was conducted through mails and personal visits.

3.2.4 Questionnaire Administration

As per the suggestion received from the people in the industry in pre-testing and validation phase, the finalized questionnaire was then sent to 60 automobile companies in the northern India. It was decided to get the questionnaire filled from a scheduler i.e. the one who prepares the schedule and a production manager i.e. one who uses the schedule. The questionnaire was sent through mails and personal visits. After two weeks of dispatch of the questionnaire first remainder was sent to the organizations that had not responded the first time. The process of was repeated for the non-respondent after another two weeks. The responses of the first time respondents were compared with those who responded late using t test, it was found that there was no significant difference in the responses.

3.3 Quantitative Tools Used

To analyze the responses received, statistical tools have been used for accurately assessing the results and to find out the relationships amongst them. Mainly two statistical tools are used in this analysis, the first one is SPSS, which is being used in the initial part of the study i.e. to perform the primary functions such data entry, replacing missing entries etc. The second tool used in the process is Smart PLS, this statistical software is being used to prepare models and find a relationship between different criteria of scheduling performance. Both these are now explained below.

3.3.1 SPSS (Statistical Package for the Social Sciences)

The “Statistical Package for the Social Sciences” (SPSS) is a software containing programs to manage the data available and a calculating variety of statistical operations. This software is widely used in the social and behavioral sciences. It is very helpful, time efficient and performs the statistical functions accurately. It was prepared by SPSS Inc. The version used in this research work is IBM SPSS Statistics 21.

3.3.2 Smart PLS (Partial Least Square)

Smart PLS is structural equation modeling (SEM) technique based on variance, which basically applies the partial least squares method with graphical user interface. The software is generally applied in empirical researches to investigate data collected from surveys and to test hypothesized relationships which have been hypothesized. Hair et al. (2011) explain PLS-SEM as a favorable method which offers vast potential for the research mainly in the areas information management and marketing. It is a technique based on regression in which the residual variances for the endogenous constructs to be reduced. Though it has several merits, it is also constrained by some demerits, like it focuses on taking full advantage of partial model structures. The first step in the PLS-SEM algorithm is to optimize measurement model parameters whereas the next step, evaluates the path coefficients in the structural model. Thus, it is generally applied to inspect the measurement model’s characteristics and deals with those that are unacceptable. Once the explained approach is properly followed, PLS-SEM results can be interpreted after assessment of the model’s measurement characteristics.

Peng and Lai (2012), as cited by Shah and Goldstein (2006), argued the role of sample sizes as an essential parameter in SEM as it has great influence on the dependability of parameter approximations, statistical power, the fitness of model for structural equation modeling. The literature on PLS-SEM quite often uses the “10 times” rule for estimating the minimum sample size condition. It has been having suggested that the “10 times” rule of thumb for deciding sample size sufficiency in PLS analysis, for the most part, connected if the conditions, for example, solid impact sizes and high unwavering quality of estimation items, are met.

Kwong and Wong (2013) suggests, as cited by (Bacon, 1999; Hwang et al., 2010; Wong, 2010) PLS is a delicate displaying way to deal with SEM without any presumptions about information dissemination. Thus, PLS-SEM turns into a critical methodology when following circumstances are experienced.

1. Small sample size

2. Little theory available about the Applications

3. Predictive accuracy is utmost

4. Accurate model condition cannot be confirmed

Hair et al. (2014) disclosed how to utilize PLS-SEM, and steps needed to be followed in a multi-stage process which includes the determination of the structural and measurement models, data accumulation and examination, the actual model estimation, and the assessment of results. In the following, the three most salient steps are characterized:

(1) Specification of the model developed

(2) Measurement model assessment

(3) Structural model assessment

Chapter IV

Survey Based Research Results

4.1 General

This chapter presents the results of a detailed survey conducted in automotive companies in the northern in India. The objective of the survey has been to assess the metrics that companies use to measure the scheduling performance. Several performance criteria such as product, process, indirect and influential factors have been defined and measures for these metrics prepared. The survey explores the importance of these criteria and their implications in planning and scheduling system. The effect of uncertainty has also been taken into consideration and the relationship of several performance criteria with environmental and executional uncertainty has been studied. The analysis of survey establishes the relationship amongst scheduling performance criteria and uncertainty.

A simple, relevant and a comprehensive questionnaire covering various aspects of scheduling performance has been specifically designed. The design methodology for framing Questionnaire has been explained in Chapter III.

4.2 Industries Covered and Response to the Survey

Several large and medium scale automobile manufacturing industries in the northern India have been surveyed. These includes large automobile OEMs to medium scale auto ancillaries manufacturing several auto parts.

The questionnaire was sent to 60 automobile industrial units. The automotive companies from northern India were selected randomly from the website of ACMA (Automotive Component Manufacturers Association of India). The response of the industry is shown in Table 4.1. A total of 35 companies responded to our urge to fill the questionnaire. These 35 companies gave us a total 89 responses which included 43 from the scheduler and 46 from the manager. After refinement of data, a total of 86 usable responses were left including 42 responses from the scheduler and 44 from the manager. The response of the manager and the scheduler is depicted in Table 4.2.

Industry	Questionnaire sent to number of companies	Companies Responded	
		Number	Percentage
Automobile	60	35	58.33%

Table 4.1: Response of the Industry

Companies Responded	Responses Received		Total Responses
	Scheduler	Manager	
35	42	44	86

Table 4.2: Response from Manager and Scheduler

The salient detail of all the firms in the automotive sector participating in the survey is compiled in Appendix D.1. The contribution of industrial experts has been acknowledged and it was sincerely admitted that this would not have been possible without the active support of all the respondents who patiently helped in this research work.

4.3 Analysis of Data

The data, after collection, has been analyzed accurately to get the proper result out of this survey based research. Initially, the data was explored for missing values, outliers, and multicollinearity. The data was checked for completeness by observing for missing values. All records in the file having more than 5% missing values and certain responses with single entry for each question were removed from the file to provide us with clean data. Once the cleaning of data was accomplished descriptive statistics was carried out, so as to reveal the primary attributes of the study. The data has been analyzed separately for manager and scheduler. The analysis of the data was carried out with following objectives:

1. To assess the significance of the measures for each scheduling performance criteria identified in the present study.

2. To evaluate the relationship amongst the scheduling performance criteria and also evaluating the effect of uncertainty on these metrics.

To fulfill the above objectives following hypotheses were postulated with the help of literature carrying different relationships amongst the different scheduling performance criteria (Daniels et al. 1995; Hoogeveen 2005; Lokuge et al. 2006; Allahverdi et al., 2008; Berglunda and Karltun 2007; Snoo et al. 2011). Hypotheses were postulated separately for managers and planners for their product and process criteria.

A. Hypotheses for managers with scheduling of product as the criteria.

H1a: Environmental uncertainty negatively influences the influencing measure.
H1b: Executional uncertainty negatively influences the influencing measure.
H1c: Influencing measure positively influences the scheduling of product.
H1d: Scheduling of product positively influences the scheduling performance.

B. Hypotheses for managers with scheduling of process as the criteria.

H2a: Environmental uncertainty negatively influences the influencing measure.
H2b: Executional uncertainty negatively influences the influencing measure.
H2c: Influencing measure positively influences the scheduling of process.
H2d: Scheduling of process positively influences the scheduling performance.

C. Hypotheses for Planners with scheduling of product as the criteria.

H3a: Environmental uncertainty positively influences the influencing measure.
H3b: Executional uncertainty positively influences the influencing measure.
H3c: Influencing measure positively influences the scheduling of product.
H3d: Scheduling of product positively influences the scheduling performance.

D. Hypotheses for Planners with scheduling of process as the criteria.

H4a: Environmental uncertainty positively influences the influencing measure.
H4b: Executional uncertainty positively influences the influencing measure.
H4c: Influencing measure positively influences the scheduling of process.
H4d: Scheduling of process positively influences the scheduling performance.

Since there were separate data files for the scheduler and the manager, the analysis was also performed separately as explained below.

4.3.1 Descriptive Analysis of data

This section includes the results of the descriptive statistics. The data of the planners and managers has been analyzed separately for all the criteria. In this analysis, the first column represents the questions used. N represents the number of responses to each question while the other columns represent the maximum and minimum mean value and standard deviation. Criteria wise descriptive analysis has been done for both product and process criteria of scheduling. All the tables of the descriptive analysis can be found in Appendix B. Therefore, the observations drawn from the descriptive analysis has been explained in the next section.

4.3.2 Observations from descriptive study

Some important observations have been drawn from the descriptive analysis of data using SPSS. The results of the descriptive study have been strategically compared between the manager and the scheduler/planner. Criteria wise comparison has been done.

4.3.2.1 Criteria focused on Scheduling of product

For scheduling of product, the measure which has got the highest mean value from both manager and planner is "Schedule shifts fit labor laws". The mean value for manager and planner were 4.07 and 4.10 respectively. These results suggest that both manager and planner find this measure of schedule shifts fitting the labor laws as most important amongst all other measures. Snoo et al. (2011) described schedule shifts fitting the labor laws as the important aspect of the fulfillment of resource utilization. The measure showing lowest mean value for managers data was "Waiting time minimized" with value 3.59, which shows that managers found waiting time minimization as the least important measure, which means that the entire scheduling of the product must take cognizance of the labor laws and the schedule shifts must be developed around the relevant labor laws. Scheduling of product should not be dependent on the waiting time minimized as this measure is an internal production issue and not to be incorporated at the manager's end, whereas the planners data show that "Resource utilization realized" as the least important measure of mean value 3.50 which means that scheduling of product should not depend on resource utilization realization should not be incorporated. Other important factors from the managers point of view were “Schedule provide information about the choices made by the stakeholders” and “Schedule within the financial budget” showing values 4.02 and 4.00 respectively. Therefore these factors have also been found important. While planner’s data shows that “Correct production routine” and “set up time minimized” were the other important measure with mean values 4.00 and 3.86 respectively. These values have been depicted in (Table 1a) and (Table 2a) in Appendix B.

4.3.2.2 Criteria focused on Scheduling of process

For scheduling of the process, both the manager and planner have found the measure “Release of the plan on time” as the most important amongst others. While the mean values for the manager and the planner were found to be 3.93 and 4.05 respectively, which means that the entire scheduling of process depends highly on the release of plan hence plans should be released on time for proper execution of scheduling plan. The least mean value for managers and planners have been found as “Schedulers micro management operations on the shop floor” showing values 3.20 and 3.26 respectively, which means scheduling of process should not depend on the schedulers micro management operations at shop floor as this measure is an internal production issue, hence it should not be incorporated from both the managers and planners end. Other important values for the mangers were “Accommodation of rush order requests on time” and “Schedulers communication with stakeholders” with mean values 3.84 and 3.80 respectively. Whereas other important measures for planner were “Scheduler easily accessible” and “Scheduler collaborates with production, store, and marketing etc.” with the mean values as 4.02 and 4.0 respectively. This shows that these measures have also got importance along with the measure with highest mean value. These values have been depicted in (Table 1b) and (Table 2b) in Appendix B.

4.2.3.3. Indirect Measures affecting Scheduling performance

Amongst the several indirect measures, both the managers and planners have chosen the measure of “Increased satisfaction of clients” as the most important which has been similar to Xing et al (2006), addressing the importance of satisfaction of clients. Whereas the mean values for the manager and the planner were found to be 3.95 and 4.14 respectively, which means that increased satisfaction of clients should be highly considered amongst all indirect measures as it is an important aspect of any business irrespective of its type and it also represents that the planners consider this more significant than managers, as each dissatisfaction of the client may result in rejections at the clients' end and may require rework. This could seriously disturb and negatively influence the planner's activity of making production plans. The measure with least mean value for the manager has been "Fewer changes in the delivery dates of consignments" with value 3.39 whereas for planners the least has been "fewer complaints from employees" with mean value equal to 3.55. This means that from manager's end, the criteria of indirect measure should not depend on fewer changes in the delivery dates of the consignment as it is an issue of supply chain management, while from the planners end indirect measures do not depend on fewer complaints from the employees as it a measure more important to the human resource department. The other important measure has been "fewer inventory shortages or surpluses" with mean values 3.57 and 3.79 for the managers and planners respectively. The values have been represented in Table 1c and 2c in Appendix B.

4.2.3.4. Influential factors of scheduling performance

The descriptive results show that the measure of "Increased schedulers knowledge and skill" as the most important amongst the all other measure, both from the point of view of planner and scheduler. The mean value for the manager and the planner are 4.0 and 3.95 respectively, which means the entire influential factors depends highly on the increased knowledge and skill of the scheduler as it is the capability of the scheduler to prepare the schedule, drives the entire process of production planning and scheduling. The least mean value for managers has been 3.43 for the measure "Reduced number of sources of information for making schedule", whereas the measure of least value for planners has been "Fixing ownership of the scheduling process in the department". This means that the criteria of influential factor should not depend on reduced number of source for making the schedule from the managers end as preparing the schedule is a prerogative of planner and hence least important to the managers. This criteria should also not depend on fixing ownership of the scheduling process in the department from the planners end as fixing ownership could lead to the sole responsibility of one person for any problem in the department regarding the schedule, therefore given least importance. The other important measure for manager has been "Increased use of automated scheduling system" with mean value found to be 3.91 and for the planners measure found was "Reduced number of sources of information for making schedule" with mean value equal to 3.74. These values have been depicted in (Table 1d) and (Table 2d) in Appendix B

4.2.3.5. Executional uncertainty in scheduling

Within several measures of executional uncertainty, the measure with highest is "Frequency of feedback from the schedule user to the scheduler is high". The mean value for manager and the planner were found to be 3.09 and 3.21 respectively, this is mainly because in any production scenario execution is an irreversible step and requires a very close monitoring and feedback to ensure that there is no serious departure from what has been planned. That is the reason it has received attention more than any other indicator. the measure with least mean for managers value equal has been "Schedule has not been executed as intended" with mean value equal to 2.16 while the least value for planners has been "Increase in slack time in schedule observed frequently" being the measure with least mean value equal to 2.26, which means that the execution of schedule as intended is highly important and steps must be taken so as to execute the schedule as per the intention from the managers end and the executional uncertainty should not depend on increase in the slack time as it is a matter of internal production department from the planners end. The other important measures have been requests for rescheduling received frequently for both manager and planner with mean value equal to 2.75 and 2.67 respectively. The values have been depicted in (Table 1e) and (Table 2e) in Appendix B.

4.2.3.6. Environmental uncertainty in scheduling

The results of the descriptive analysis show the difference in the opinion when it comes to the measures of environmental uncertainty. The highest mean value found for the managers was 3.20 for the measure "Frequency of new information delivered to the scheduler" and highest mean value for the planner was 3.40 for the measure "High frequency in transit delay observed". This means that from managers end frequency of new information added to the scheduler could help in tackling the uncertainty in the environment and high frequency of in transit delay should be managed properly and schedule must be prepared to take in transit delay into consideration, from planners end. The other important measures for the executional uncertainty has been "Frequency of rush orders observed" for both managers and planners with mean values equal to 2.64 and 3.38 respectively. These values have been depicted in (Table 1f) and (Table 2f) in Appendix B.

4.4. Model development with PLS-SEM

After the descriptive analysis of data, unique research model has been developed to evaluate the relationships between the scheduling performance criteria and their measures, in PLS-SEM. In this, when a model is assessed, the constructs has been shown by ellipses and indicator has been shown by rectangles. The factor ellipses and arrow creating them are called the inner or structural model. The indicator rectangles and arrows connecting them are called the outer or measurement model. There are some terms pertaining to the inner or structural model. A latent variable is exogenous if it is not an effect of any other latent variable in the model i.e. there are no incoming arrows from other latent variables. A latent variable is endogenous if it is an effect of at least one other latent variable (Garson 2016). This is illustrated in Figure 4.1.

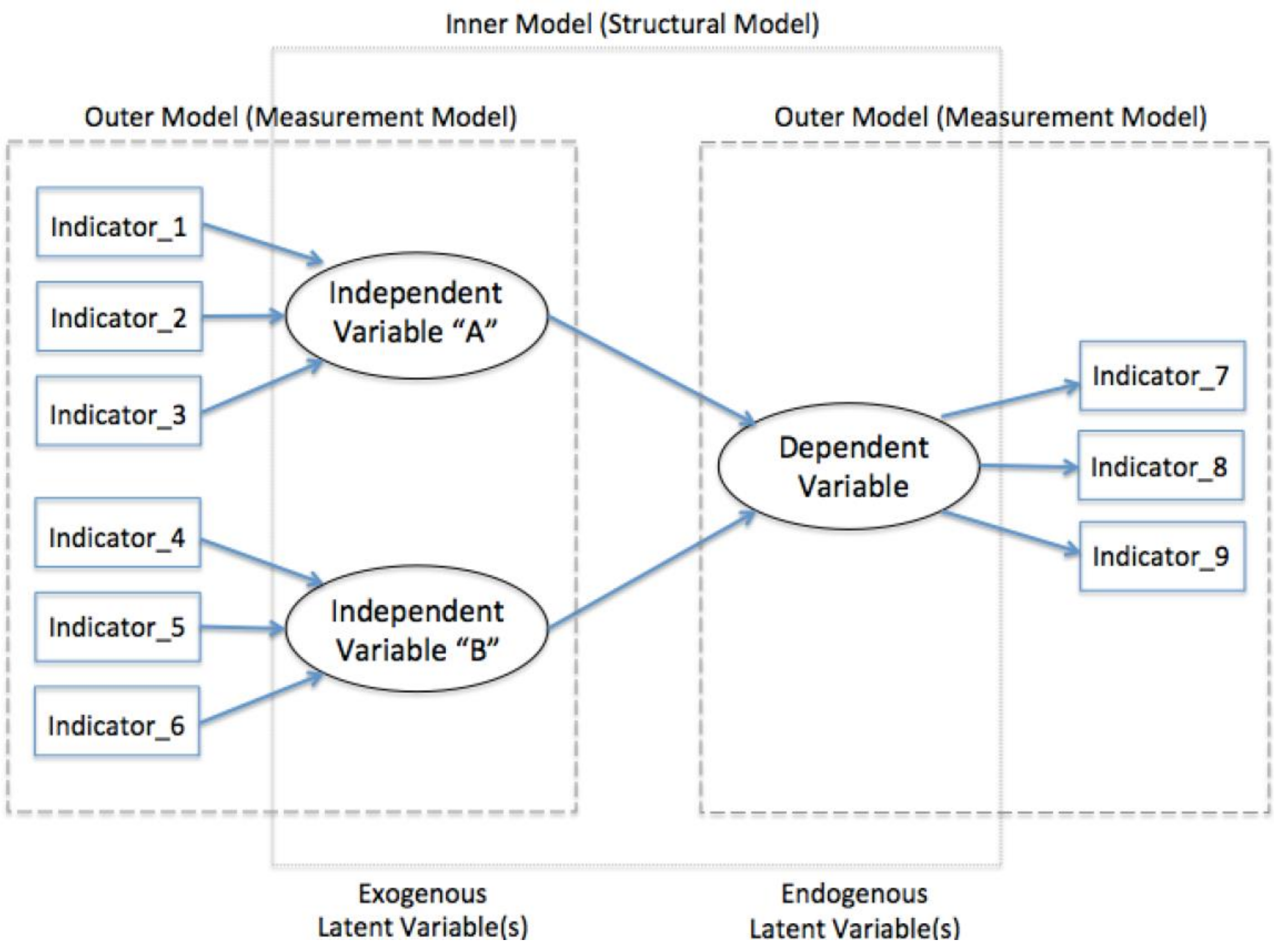


Figure 4.1 A Simplified Reflective PLS-SEM Model (adapted from Backhaus et al. 2000)

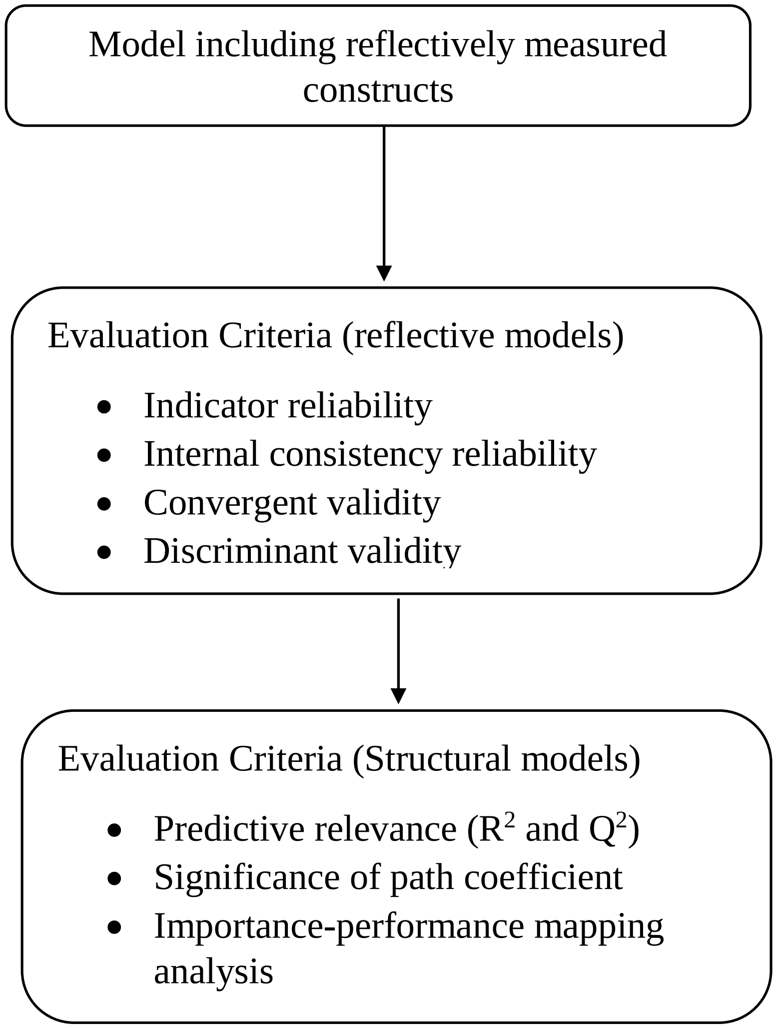


Figure 4.2 Evaluation criteria for a model with reflective constructs

All the constructs in models developed for managers, planners are reflective. These are the models in which factor are connected to the indicator variables through arrow, representing the one directional relationship between construct and illustrative indicator variables (Garson 2016). The evaluation criteria used for both measurement and structural have been represented in Figure 4.2. First of all measurement model has been assessed, the constructs and indicators have been evaluated on the evaluation criteria, to judge the validity and reliability of the constructs and indicators. The structural models are then assessed on its evaluation criteria, once measurement assessment has been found fit. Separate measurement models have been prepared for both manager and planner/scheduler. The following evaluation criteria have been considered for the study.

4.4.1. Composite reliability

In reflective models, Composite reliability tests the convergent validity. It is a preferred over Cronbach's alpha because Cronbach's alpha tends to over- or undervalue the reliability of the scale. The reason behind the composite reliability being preferred over Cronbach's alpha for testing the reliability of indicators in measurement models, is that it may prompt to higher approximations of correct reliability. Composite reliability fluctuates between 0 and 1, with 1 as the ideal evaluated reliability. When a model is assessed for empirical research, the composite reliability value greater than .6 is acceptable and for confirmatory use the value equal to or above 0.70 is considered satisfactory; whereas the value equal to or above .80 is accepted as the good for confirmatory research. (Garson 2016).

4.4.2. Cronbach's alpha

Cronbach's alpha checks the convergent validity of the indicators for latent variables. The Cronbach's alpha is also known for estimating the internal coherance of reliability and thus as the value of Cronbach's alpha increase the inter correlations among indicators also increase, and is thus known as of test scores. By convention, the same cutoffs value for Cronbach's alpha is greater or equal to .80 for a good scale, 0.70 for an acceptable scale, and 0.60 for a scale for exploratory purposes. If the value is less than 0.70, Cronbach's alpha considered as bias hence the values below this cut off value could be ignored. However, Cronbach's alpha is considered as conventional measure which often undervalue reliability (Garson 2016).

4.4.3. Average variance extracted (AVE)

AVE i.e. average variance extracted is a measure to assess convergent and divergent of the indicators which a construct is capable of describing. For a satisfactory model, the value of AVE should be above 0.50 and it should also be more than the value of cross-loadings, which means factors must be capable of explaining at least half the variance of each indicators. AVE less than 0.50 shows that error variance may have exceeded the explained variance (Garson 2016).

4.4.4. The Fornell and Larcker discriminant validity criterion

In Fornell–Larcker criterion AVE have been used to establish discriminant validity. The square root of AVE must be greater than the correlation of constructs with all other constructs for any latent variable. Therefore it can be established that for any latent variable, the variance shared latent variable should always be less than the variance shared with indicators.The results show that in this criterion, the square root of AVE is depicted in the diagonal cells and relationships between them is shown below. (Garson 2016).

Once the reliability and validity of the outer models have been recognized, it shows that model is fit for structural model analysis, some steps are needed to be considered to evaluate the hypothesized relationships within the structural/inner model. Therefore, the model has been evaluated on the evaluation criteria of the coefficient of determination (R^2**)**, bootstrap, blindfolding, and importance-performance map analysis (IPMA).These important parameters have been explained briefly:

4.4.5. Coefficient of determination R^2

The R^2 shows of the model's predictive accuracy. R^2 indicates the percentage of a construct's variance in the model. The value of R^2 could also be seen as representing the exogenous variable's collective result on the endogenous variable. Its value varies from 0 to 1 with 1 showing complete predictive accuracy (Hair et al., 2014). According to Cohen (1988) R^2 values for endogenous latent variables can be assessed substantial if $R^2 \geq 0.26$, moderate for $R^2 \geq 0.13$ and weak for $R^2 \geq 0.02$.

4.4.6. Bootstrap

Bootstrap has been used to find the level of significance between the constructs. Bootstrapping can be described as a resampling technique which pulls a large number of subsamples from the main data and estimates models for each subsample. Therefore, a bootstrapping procedure drawing on 46 cases and 5000 re-samples and using 'no sign change option' has been performed for significance testing for the loadings. Critical *t*-values for a two-tailed test are 1.65 (significance level = 10 percent), 1.96 (significance level = 5 percent), and 2.58 (significance level = 1 percent).

4.4.7. Blindfolding

Blindfolding is a measure cross-validation strategy and shows cross validated communality and cross validated redundancy for constructs as well as indicators. The predictive relevance (Q^2) of the model is evaluated using this construct. Q^2 is also known as Stone-Geisser Q^2. It is applicable only to reflectively models, Q^2 greater than 0 shows that the model is capable of predicting the given constructs under analysis. The redundancy estimation of Q^2 is more consistent than communality with the PLS-SEM, as it emphasizes on paths involving the endogenous variables (Hair et al., 2014).

4.4.8. Importance-performance map analysis (IPMA)

IPMA is a very important parameter to check the performance and importance of the model. This test can be very helpful for the manager in finding the performance and importance, though it gives no evidence about the model apart from which is already there in the model. (Garson 2016). It is very important while comparing the number of constructs considered in the model. The X and Y axis in the IPMA figure depicts the importance and performance respectively.

4.5 Model evaluation with PLS-SEM

In this section measurement model has been prepared and the model has been tested for validity and reliability. Once the model found fit in the measurement model, the hypothesized relation has been evaluated in the structural model. Hence, the coefficient of determination (R^2), blindfolding, and importance-performance map analysis (IPMA) have also been conducted.

4.5.1. Measurement or Outer Model evaluation for Managers

The outer model is also known as the “measurement” model because it useful in explaining how constructs of the structural model can be measured. In other words, the outer model defines the meaning of the constructs in the structural model (Garson 2016). The loadings in the reflective model varies from 0 to 1. In general, stronger and more reliable the measurement model is obtained if loadings are larger. Outer model loadings appear in the graphical model, these loadings should be higher than 0.70. By convention, the indicator with a measurement loading in the 0.40 to 0.70 range should not be considered (Henseler, Ringle, & Sarstedt, 2012) as cited by (Garson 2016). Therefore the all those indicators below 0.70 has been dropped and only the indicators with loadings more than 0.70 were chosen. These indicators have been eliminated so as to get the model significant. In the measurement model, the influence of the both uncertainties i.e. environmental and executional has been studied on the product and process related criteria separately. The convergent reliability and validity have also been tested as explained below.

4.5.1.1. *Considering scheduling of product as criteria*

Measurement Model Analysis (PLS Algorithm)

The measurement model for managers with product as the criteria has been shown below in Figure 4.3, with all its constructs and indicators and their path coefficient values. Measurement loading in the below 0.70 range should be dropped (Hair et al., 2014), but in this model the indicators Env_2 and Env_3 have been retained in the model as these are theoretically significant dimension.

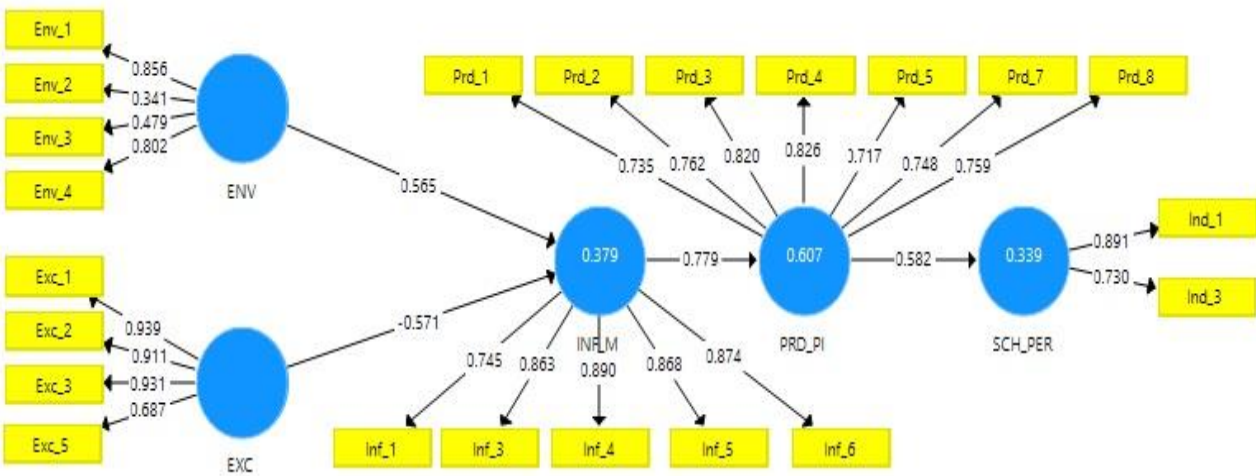


Figure 4.3 Measurement Model (Managers: Scheduling of Product)

As explained in section 4.4(A) composite reliability tests the convergent validity in reflective models and the value of composite reliability greater than 0.70 regarded as satisfactory for the research (Henseler, Ringle, & Sarstedt, 2012). As shown in Figure 4.4 all the indicators have the values greater than 0.70, thereby, ending support for the measures' convergent validity.

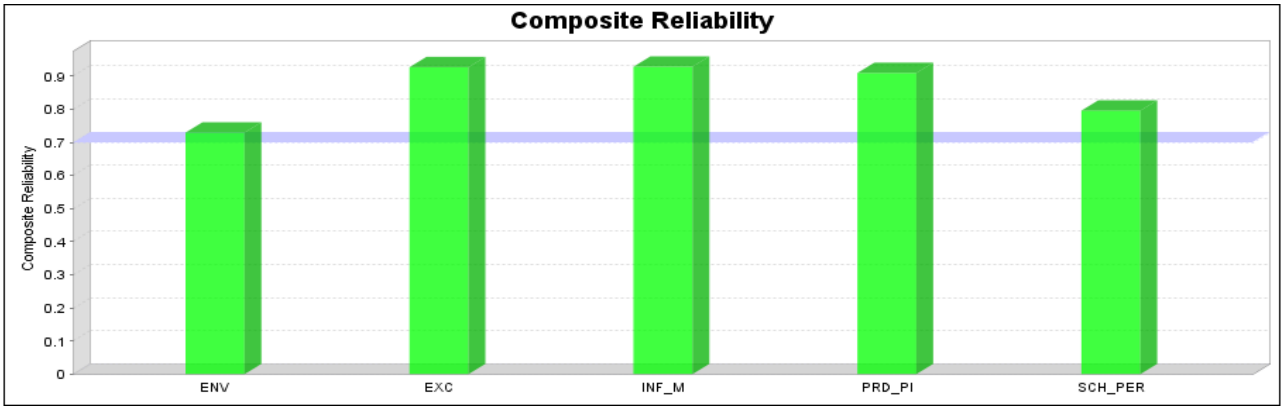


Figure 4.4 Composite Reliability (Managers: Scheduling of Product)

Cronbach's alpha also tests the reliability and validity of the model. As explained in the above section, the values of the Cronbach's alpha should be greater than 0.70. The Table. 4.3 shows that all the values except the Environmental uncertainty all other indicators are showing values greater than 0.70, but the environmental uncertainty has still been kept as a parameter as it is the important part of the research.

Indicator	Cronbach's Alpha
Environmental uncertainty	0.786
Executional uncertainty	0.897
Influential Measures	0.903
Scheduling Product related issues	0.885
Scheduling Performance	0.507

Table 4.3 Cronbach's Alpha (Managers: Scheduling of Product)

AVE value test both the convergent as well as the divergent validity. The model with AVE value greater than 0.5 is considered as an adequate model. The value below .5 means error variance exceeds the explained variance. As shown in Table 4.4 all the indicators, except environmental uncertainty, which is showing AVE value less than .5. Hence the model can be said to be adequate for further analysis.

Indicator	Average Variance Extracted (AVE)
Environmental uncertainty	.430
Executional uncertainty	.762
Influential Measures	.722
Scheduling Product related issues	.589
Scheduling Performance	.663

Table 4.4 Average Variance Extracted (AVE) (Managers: Scheduling of Product)

The results discriminant validity using the Fornell–Larcker discriminant validity criterion has been shown in Table 4.5. According to this criteria, if the top number (which is the square root of AVE) in any factor column is higher than the numbers (correlations) below it, there is discriminant validity.

	Env_U	Exc_U	Inf_M	Prd_PI	Sch_PR
Env_U	0.656				
Exc_U	0.413	0.873			
Inf_M	.330	-0.337	0.850		
Prd_PI	.246	-0.296	0.768	0.779	
Sch_PR	077	-0.374	0.712	0.582	0.813

Table. 4.5 Discriminant Validity (Managers: Scheduling of Product)

The results of all these tests carried out above to check the convergent and the divergent validity of the measurement model and the results have been found to be positive. Hence it can be concluded that the measurement model prepared for the managers taking scheduling of product as the criteria for performance is fit for further studies.

4.5.1.2 Considering scheduling of Process as criteria

In this section the measurement model has been assessed considering scheduling of process as the main criteria and several tests have been employed to check the validity and reliability of the model.

Measurement Model Analysis (PLS Algorithm)

The measurement model has been prepared for scheduling of process as the criteria. The model shown in the Figure. 4.5, all the constructs and indicators and their path coefficient values. The loading in the below .70 range should be dropped (Hair et al., 2014), but in this model the indicators, Env_2 and Env_3 have been retained in the model as these are theoretically significant dimension.

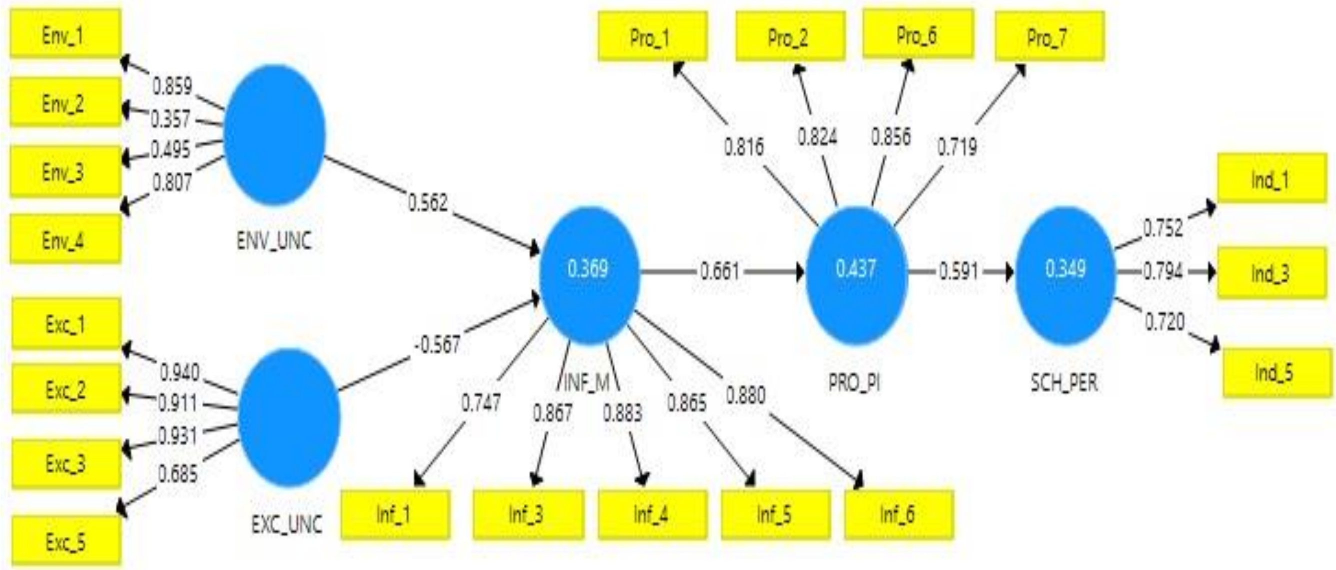


Figure 4.5 Measurement Model (Managers: Scheduling of Process)

The composite reliability of all the indicators is above 0.7, as shown in the Figure. 4.6. Hence the all the indicators are valid and reliable.

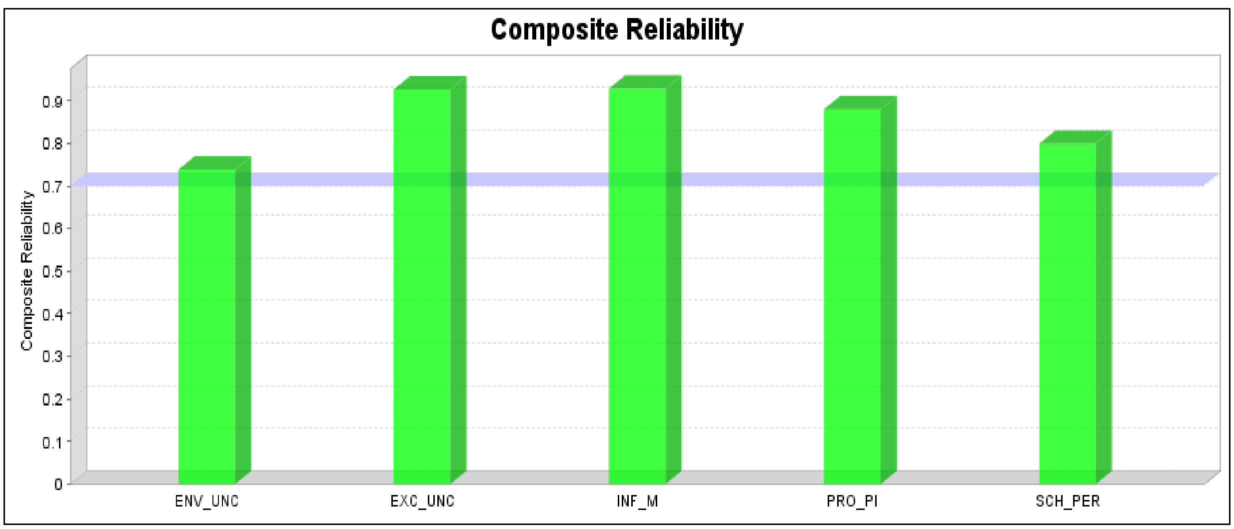


Figure 4.6 Composite Reliability (Managers: Scheduling of Process)

All the indicators in Table 4.6 have Cronbach alpha value above 0.7, except environmental uncertainty which is still considered being the important part of the research. This means that model is valid and reliable.

Indicator	Cronbach's Alpha
Environmental uncertainty	0.786
Executional uncertainty	0.897
Influential Measures	0.903
Scheduling Process related issues	0.818
Scheduling Performance	0.638

Table 4.6 Cronbach's Alpha (Managers: Scheduling of Process)

All the indicators showing AVE values greater than 0.5, except the value of environmental uncertainty. Hence the model according to this test of reliability. The results have been depicted the Table 4.7.

Indicator	Average Variance Extracted (AVE)
Environmental uncertainty	0.440
Executional uncertainty	0.762
Influential Measures	0.722
Scheduling Process related issues	0.649
Scheduling Performance	0.517

Table 4.7 Average Variance Extracted (AVE) (Managers: Scheduling of Process)

The results discriminant validity has been shown in Table 4.8. The results show that there is discriminant validity as the square root of AVE has been greater than the correlation of the constructs with all other constructs.

	Env_U	Exc_U	Inf_M	Prd_PI	Sch_PR
Env_U	0.663				
Exc_U	0.420	0.873			
Inf_M	0.323	-0.331	0.850		
Prd_PI	0.069	-0.159	0.661	0.805	
Sch_PR	0.029	-0.301	0.642	0.591	0.759

Table 4.8 Discriminant validity (Managers: Scheduling of Process)

4.5.2 Structural model evaluation: Managers

In this section, the structural model, hypothesized for managers has been evaluated on the parameters explained above. The criteria for scheduling of product and process has been evaluated separately.

4.5.2.1 Considering scheduling of product as criteria

In this section, the structural model evaluation for the data of the managers has been carried out for scheduling of product as the criteria.

The structural has been prepared for managers, taking scheduling of product as the criteria as shown in Figure 4.5. The results of bootstrap have been shown in Table 4.9, which shows that environmental uncertainty in influential factors. The bootstrap has been calculated at 5% significance level with 44 cases and 5000 subsamples.

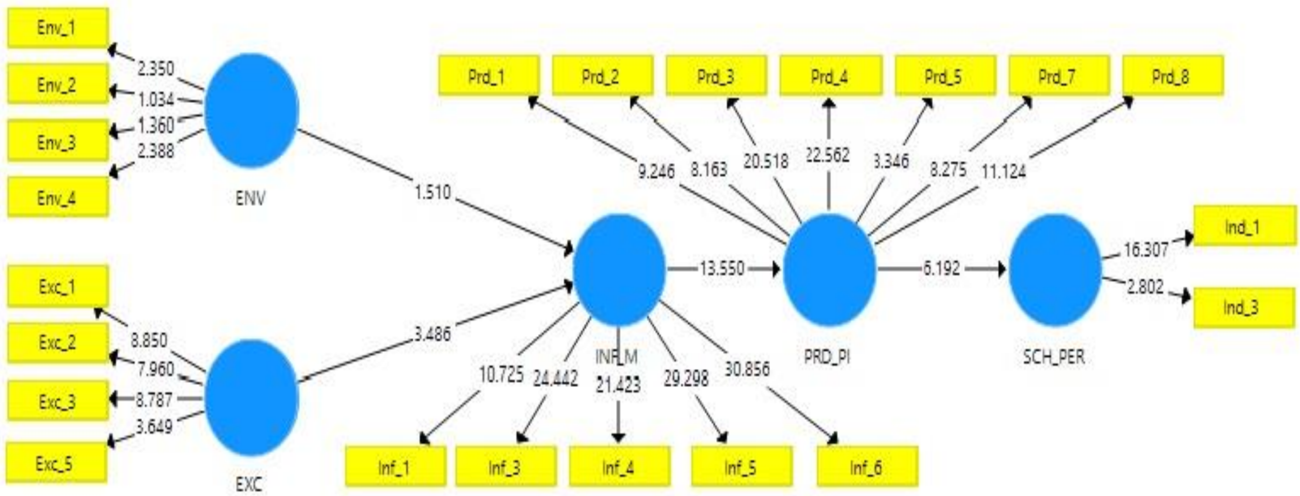


Figure 4.7 Structural Model (Bootstrap)

(44 Cases and 5000 re-samples)

(Managers: Scheduling of Product)

Added Relationships	Original sample	T-Statistics	P Values
Env_U → Inf_M	0.535	1.510	0.128
Exc_U → Inf_M	-0.594	3.486	0.001
Inf_M → Prd_PI	0.779	13.550	0.000
Prd_PI → Sch_PER	0.582	6.192	0.000

Table 4.9 Added Relationships (Managers: Scheduling of Product)

Blindfolding has been carried out check the predictive accuracy of the structural model. Results of the blindfolding have been summarized below in Table 4.10. All the value are above zero, therefore it can be concluded that has predictive accuracy.

Performance criteria	Cross validated redundancy	Cross validated communality
Influencing Measures	.228	.575
Product Performance Issues	.312	.434
Scheduling Performance	.158	.053

Table 4.10 Blindfolding results (Managers: Scheduling of Product)

IPMA has been calculated taking scheduling performance as the target construct and the effect its predecessor construct on the scheduling performance has been calculated and the result of the IPMA has been depicted in the Figure 4.8, while the importance and performance of different constructs have been tabulated in Table 4.11.

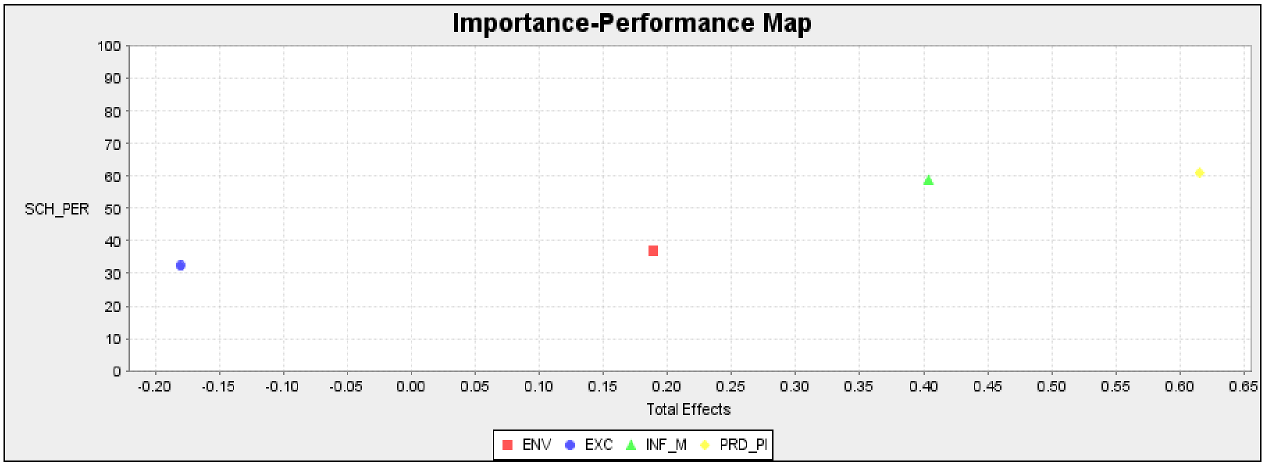


Figure 4.8 IPMA Map (Managers: Scheduling of Product)

Latent Variable	Importance	Performance
Sch_PR	Target	63.891
Prd_PI	0.6151	60.874
Inf_M	0.4041	58.914
Exc_Unc	-0.1816	37.235
Env_Unc	0.1952	32.280

Table 4.11 IPMA Results (Managers: Scheduling of Product)

4.5.2.2 Considering scheduling of process as criteria

In this section, the structural model evaluation for the data of the managers has been carried out for scheduling of product as the criteria.

The structural model for the managers by taking scheduling of process as the main criteria have been prepared using bootstrap, to check the significance of the model as shown in the Figure. 4.9.

The results of bootstrap have been shown in the Table 4.12, which show that the relationship between environmental uncertainty and influential factor has been insignificant. The bootstrap has been calculated at the significance level of .05.

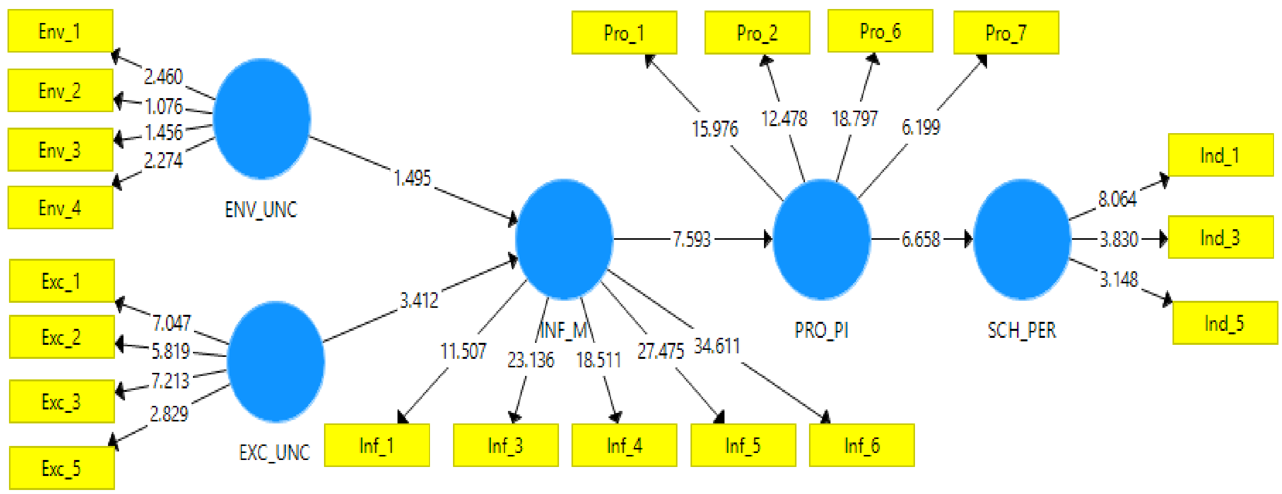


Figure 4.9 Structural Model (Bootstrap)

(44 Cases and 5000 re-samples)

(Managers: Scheduling of Process)

Added Relationships	Original sample	T-Statistics	P Values
Env_U → Inf_M	0.562	1.495	0.136
Exc_U → Inf_M	-0.567	3.412	0.001
Inf_M → Pro_PI	0..661	7.593	0.000
Prd_PI → Sch_PER	0.591	6.658	0.000

Table 4.12 Added Relationships (Managers: Scheduling of Process)

The results of the blindfolding for managers considering the scheduling of process as the performance criteria has been shown in the Table 4.13. All the value are above zero, therefore it can be concluded that has predictive accuracy.

Performance criteria	**Cross validated redundancy**	**Cross validated communality**
Influencing Measures	.225	.574
Product Performance Issues	.269	.408
Scheduling Performance	.129	.137

Table 4.13 Blindfolding results (Managers: Scheduling of Process)

IPMA has been calculated taking scheduling performance as the target construct and the effect its predecessor construct on the scheduling performance has been calculated and the result of the IPMA has been depicted in the Figure 4.10, whereas the importance and performance of the constructs have been tabulated in the Table 4.14.

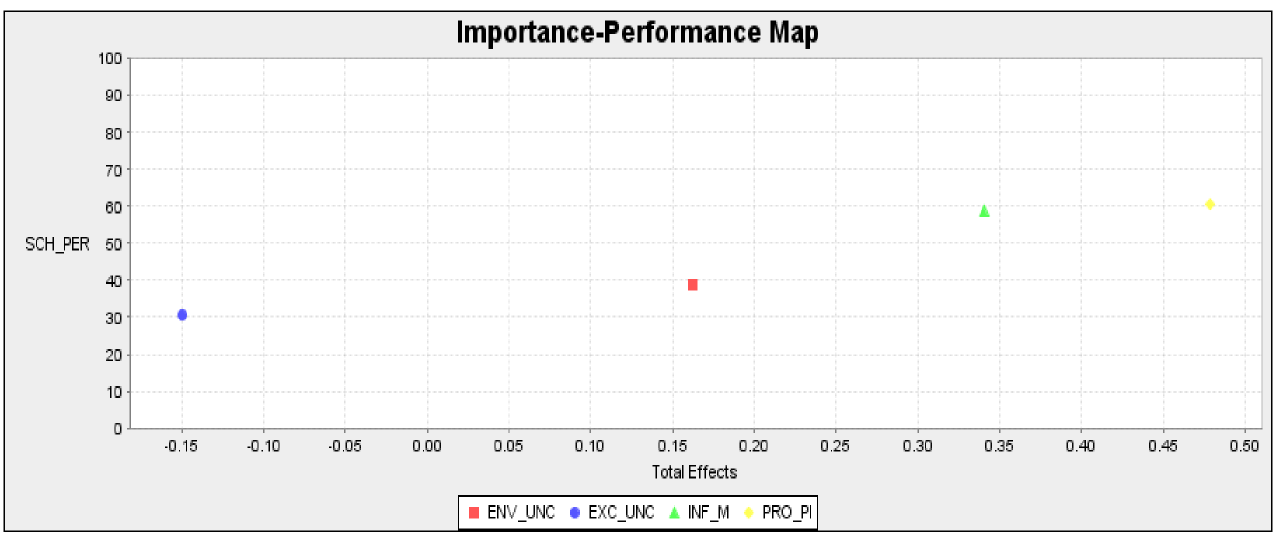


Figure 4.10 IMPA (Managers: Scheduling of Process)

Latent Variable	Importance	Performance
Sch_PR	Target	64.007
Pro_PI	0.4785	60.408
Inf_M	0.3389	58.518
Exc_Unc	-0.1496	32.251
Env_Unc	0.1583	37.422

Table 4.14 IPMA Results (Managers: Scheduling of Process)

4.5.3 Measurement or Outer Model evaluation: Planners

In this section, the measurement models have been prepared by considering both product and process criteria for planners. The model was then tested for their validity and reliability.

4.5.3.1. Considering scheduling of product as criteria

In this section measurement model has been assessed for the planners considering the scheduling of product as the prime criteria for performance of the scheduling.

Measurement Model Analysis (PLS Algorithm)

The measurement model is presented in the Figure 4.11. The model has been prepared by taking the important convention of keeping the outer loadings value greater than 0.7 and the values less than 0.7 have been dropped.

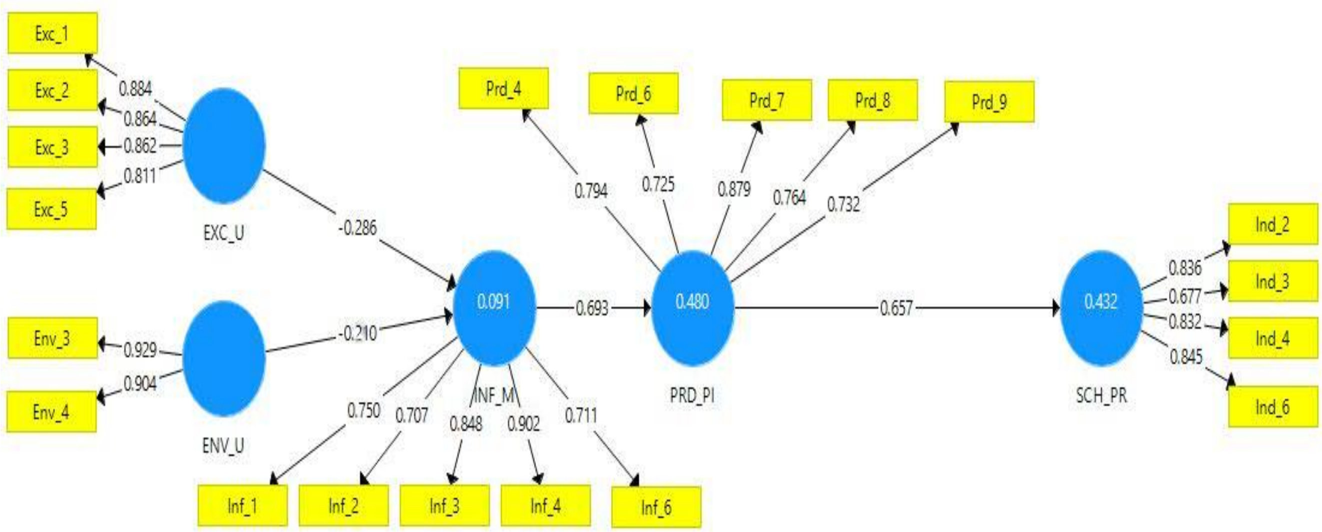


Figure 4.11 Measurement model (Planners: Scheduling of Product)

The Fig. 4.12 shows the composite reliability of the indicators, and all the indicators have got values greater than 0.7, which implies that model is reliable and valid.

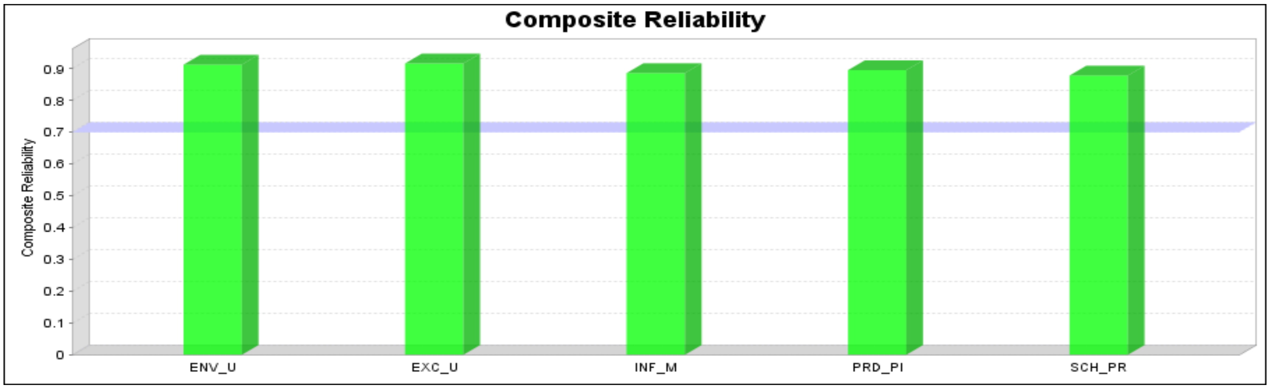


Figure 4.12 Composite Reliability (Planners: Scheduling of Product)

Cronbach's alpha also test the reliability and validity of the model. The Table 4.15 depicts the Cronbach's alpha for all the indicators and all these values have been found above .7 hence the model can be said to valid according to this test.

Indicator	Cronbach's Alpha
Environmental uncertainty	.810
Executional uncertainty	.879
Influential Measures	.845
Scheduling Product related issues	.840
Scheduling Performance	.813

Table 4.15 Cronbach's Alpha (Planners: Scheduling of Product)

The AVE value for all the indicators were above .5 hence the measurement model prepared can be said to be valid according to this test.

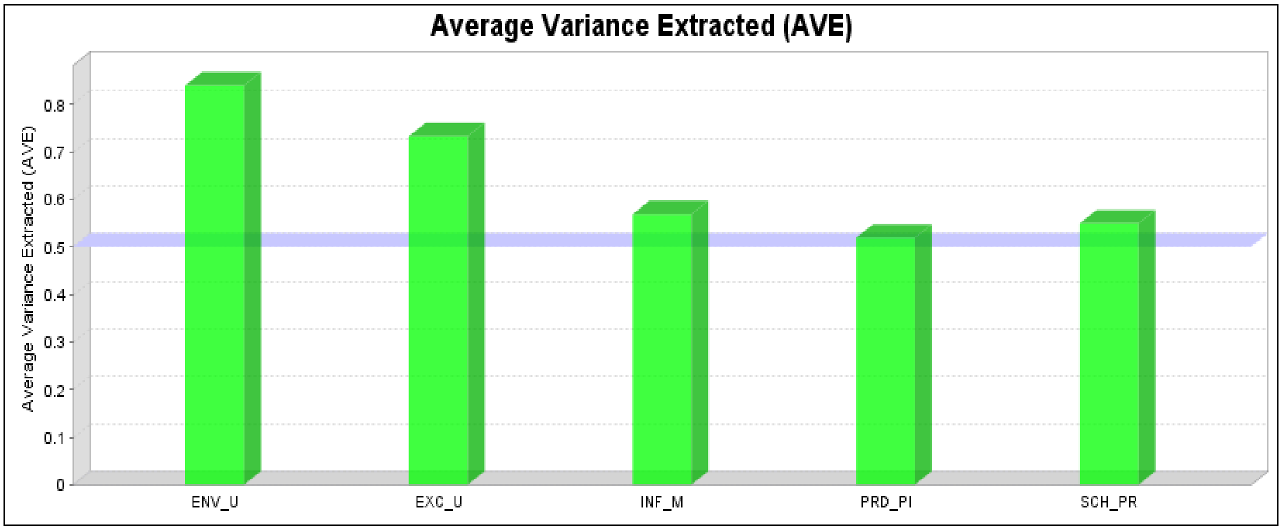


Fig. 4.13 Average Variance Extracted (AVE) (Planners: Scheduling of Product)

The results of criterion have shown below in Table 4.16. The results show that there is discriminant validity as the square root of AVE has been greater than the correlation of the constructs with all other constructs in the structural model.

	Env_U	Exc_U	Inf_M	Prd_PI	Sch_PR
Env_U	0.916				
Exc_U	-0.050	0.856			
Inf_M	-0.127	-0.319	0.754		
Prd_PI	-0.199	-0.135	0.680	0.721	
Sch_PR	-0.187	-0.282	0.684	0.662	0.741

Table 4.16 Discriminant Validity (Planners: Scheduling of Product)

As the measurement model shown in Figure 4.11 showing reasonable results, hence it can be concluded that the measurement model prepared, fit for further evaluation.

4.5.3.2 Considering scheduling of Process as criteria

In this section the measurement model has been prepared for the planners, taking scheduling of process as the criteria for scheduling performance. Several important tests have also been conducted to test the validity and reliability of the model.

Measurement Model Analysis (PLS Algorithm)

In this section, the measurement model has been prepared as shown in the Figure 4.14. The model shows all the constructs and indicators for planners in the process criteria of scheduling. The outer loadings with value less than 0.7 have been eliminated.

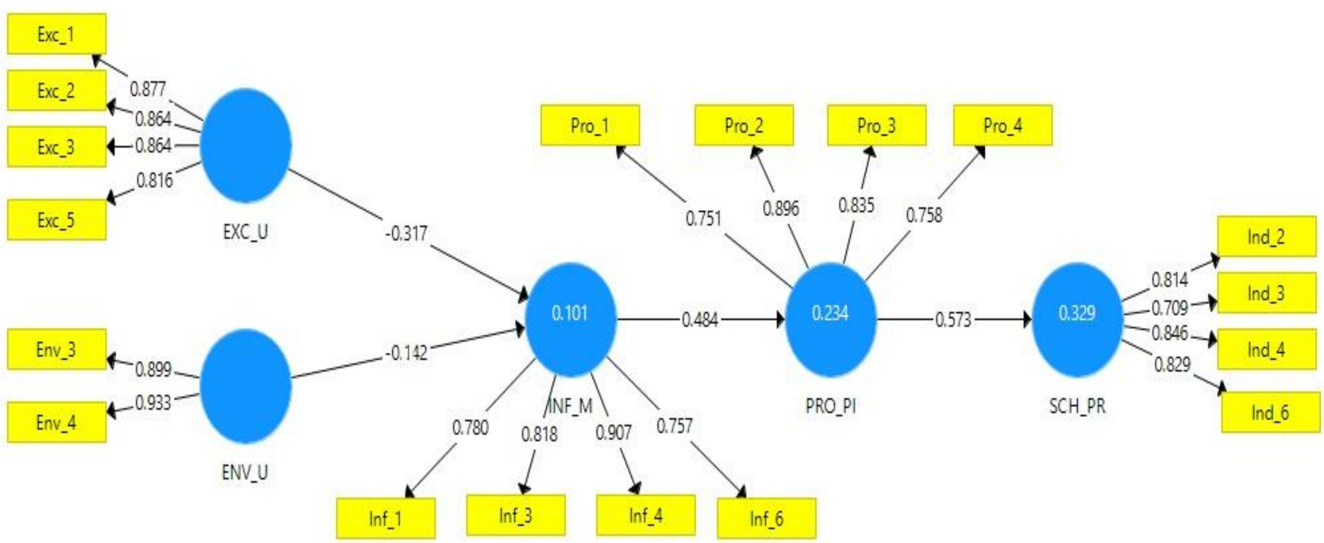


Figure 4.14 Measurement Model (Planners: Scheduling of Process)

The composite reliability for all the indicators has been found above 0.7, hence model can be said to have passed this test of reliability as shown in Figure 4.15.

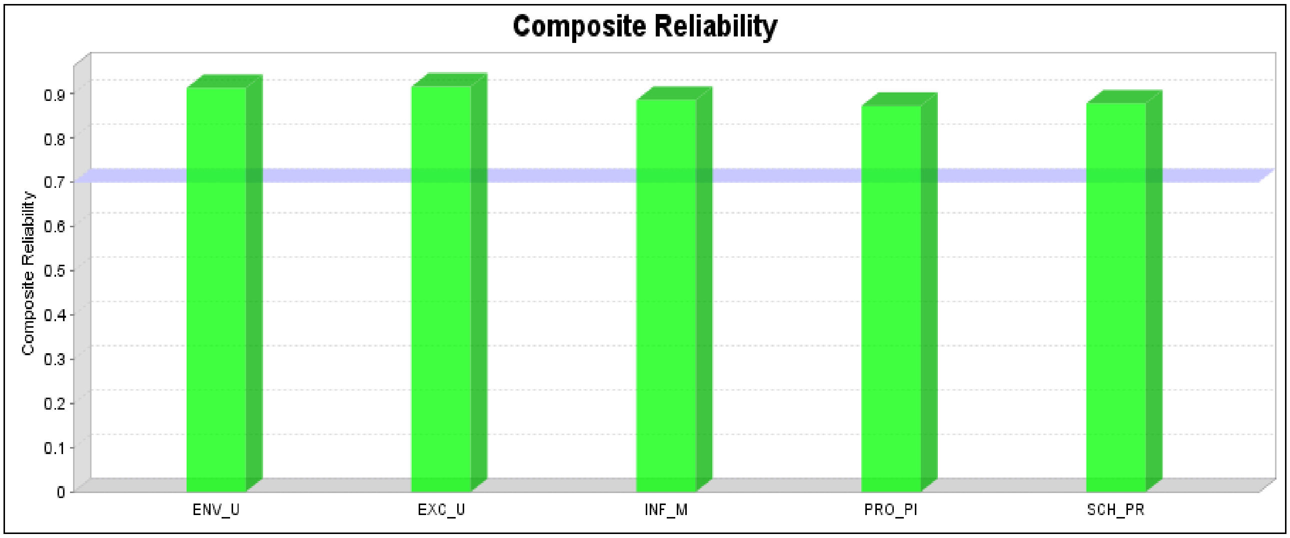


Figure 4.15 Composite Reliability (Planners: Scheduling of Process)

The model satisfies this test as well as all the indicators have been showing values greater than .7 as shown in Table 4.17.

Indicator	Cronbach's Alpha
Environmental uncertainty	.810
Executional uncertainty	.879
Influential Measures	.845
Scheduling Process related issues	.840
Scheduling Performance	.813

Table 4.17 Cronbach's Alpha (Planners: Scheduling of Process)

The AVE value shown in Figure 4.16, all the indicators have the values greater than .5, hence the model can be said to be valid according to this test.

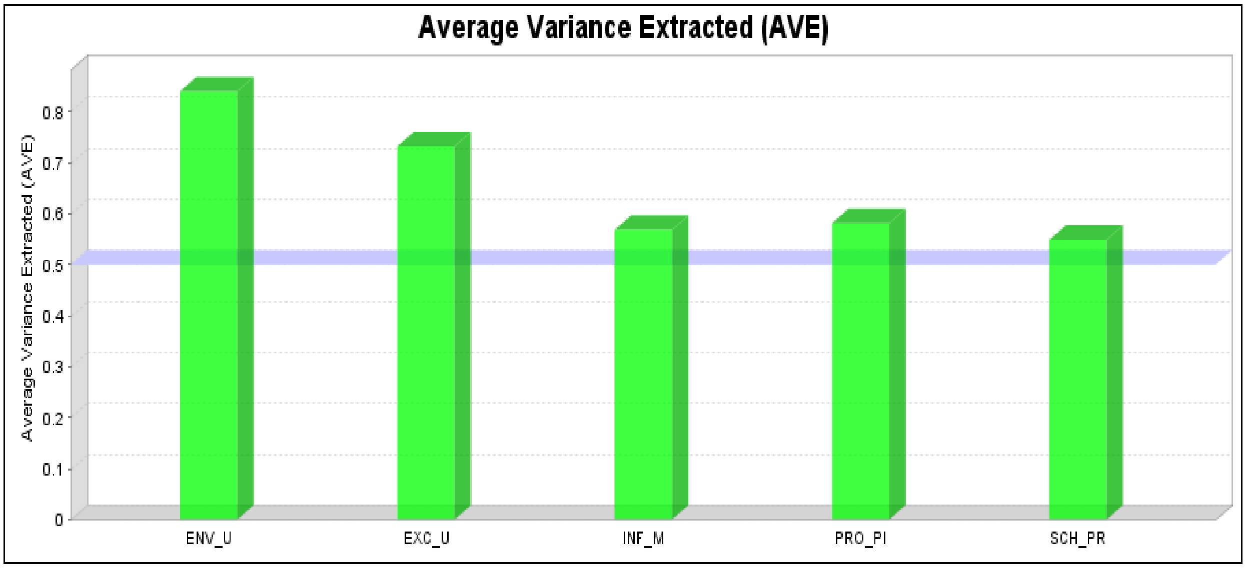


Figure 4.16 Average Variance Extracted (AVE) (Planners: Scheduling of Process)

The results of the Fornell–Larcker discriminant validity criterion has been depicted below in the Table 4.18, shows that there is discriminant validity, as the square root of AVE has been greater than the correlation of the constructs with all other constructs in the structural model.

	Env_U	Exc_U	Inf_M	Prd_PI	Sch_PR
Env_U	0917				
Exc_U	-0.049	0.856			
Inf_M	-0.121	-0.320	0.754		
Prd_PI	-0.080	-0.224	0.491	0.763	
Sch_PR	-0.164	-0.302	0.711	0.617	0.741

Table 4.18 Discriminant Validity (Planners: Scheduling of Process)

4.5.4 Structural Model evaluation: Planners

Once the measurement model was found to be fit according to the several tests conducted for reliability and validity. The structural or inner model contains construct which are connected to the other constructs through an arrow. Structural models have been separately assessed for managers and planners.

4.5.4.1 Considering scheduling of product as criteria

In this section, the structural model evaluation for the data of the planners have been carried out for scheduling of product as the criteria.

Structural model has been assesed for planners, considering scheduling of product as the main criteria using bootstrap as shown in Figure 4.17. It helps to find significance between the constructs. The results of the bootstrap have been shown in the Table 4.19, all the relationships being significant.

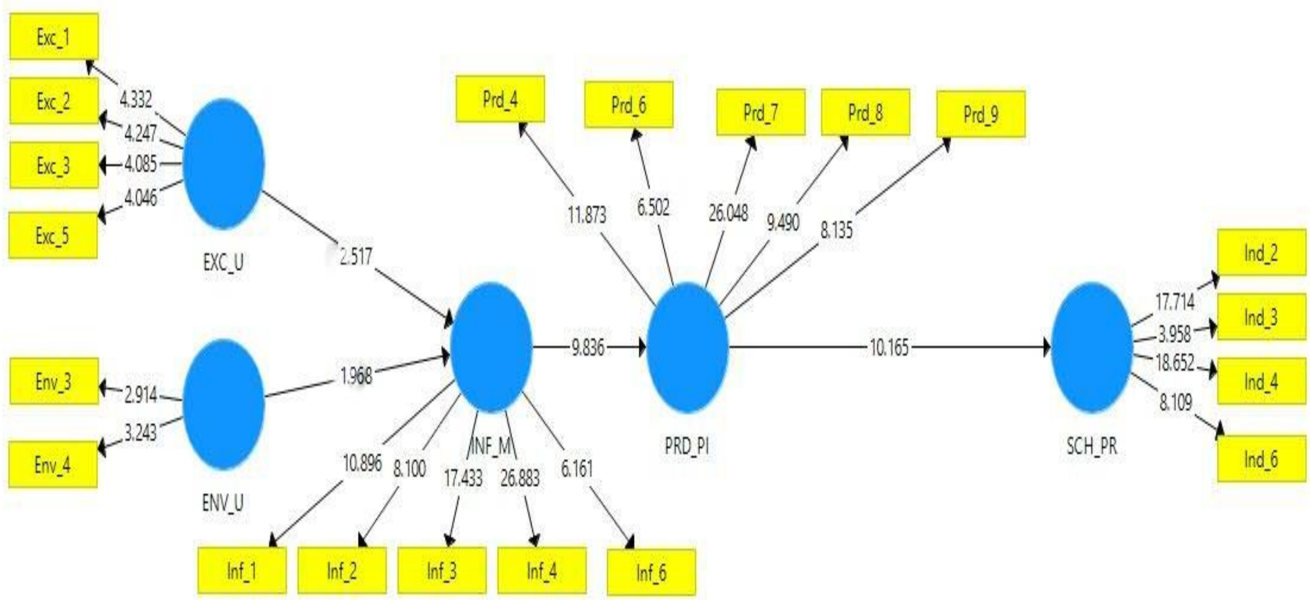


Fig. 4.17 Structural Modal (Bootstrap)

(42 Cases and 5000 re-samples)

(Planners: Scheduling of Product)

Added Relationships	Original sample	T-Statistics	P Values
Env_U → Inf_M	-0.210	1.968	0.027
Exc_U → Inf_M	-0.286	2.517	0.007
Inf_M → Prd_PI	0.693	9.837	0.000
Prd_PI → Sch_PER	0.657	10.165	0.000

Table 4.19 Added Relationship (Planners: Scheduling of Product)

The results of the blindfolding for planners considering the scheduling of product as the performance criteria has been shown in the Table 4.32. All the value are above zero, therefore it can be concluded that has predictive relevance.

Performance criteria	Cross validated redundancy	Cross validated communality
Influencing Measures	.038	.421
Product Performance Issues	.263	.396
Scheduling Performance	.240	.401

Table 4.20 Blindfolding results (Planners: Scheduling of Product)

IPMA has been calculated taking scheduling performance as the target construct and the effect its predecessor construct on the scheduling performance has been calculated and the result of the IPMA has been depicted in the Figure 4.18, whereas the importance and performance of the constructs have been tabulated in the Table 4.21.

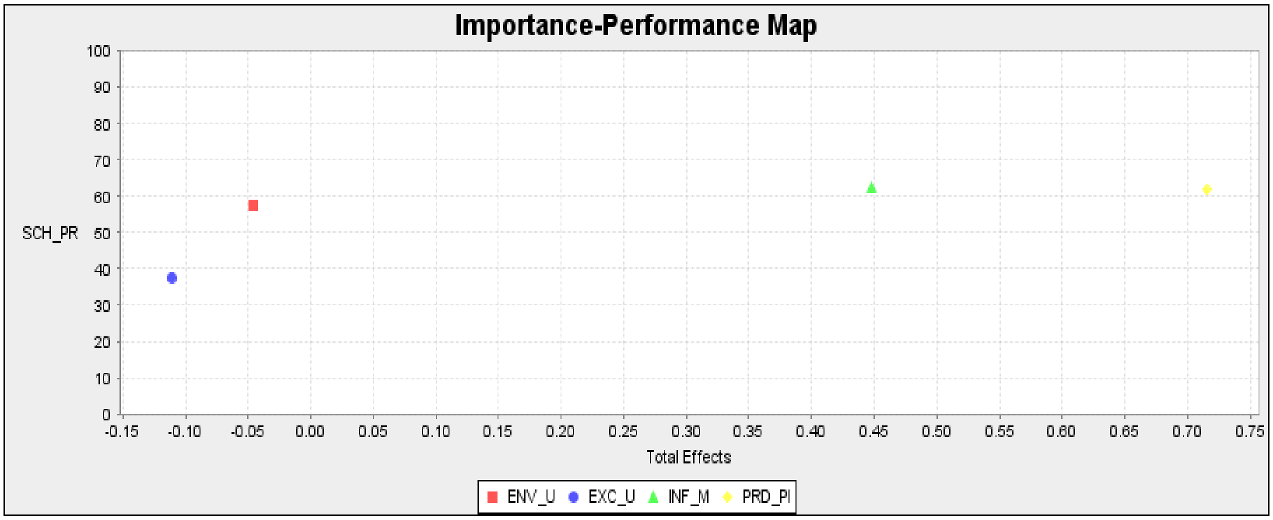


Figure 4.18 IPMA Map (Planners: Scheduling of Product)

Latent Variable	Importance	Performance
Sch_PR	Target	58.254
Prd_PI	0.7538	62.696
Inf_M	0.5017	62.007
Exc_Unc	-0.0402	37.509
Env_Unc	-0.1111	57.528

Table 4.21 IPMA Results (Planners: Scheduling of Product)

4.5.4.2. Considering scheduling of process as prime criteria

Structural model has been prepared for planners, considering scheduling of process as the main criteria using bootstrap as shown in Figure 4.19 and Table 4.22 show the added relationship between the constructs and it also shows that also the hypothesized relationship has been significant.

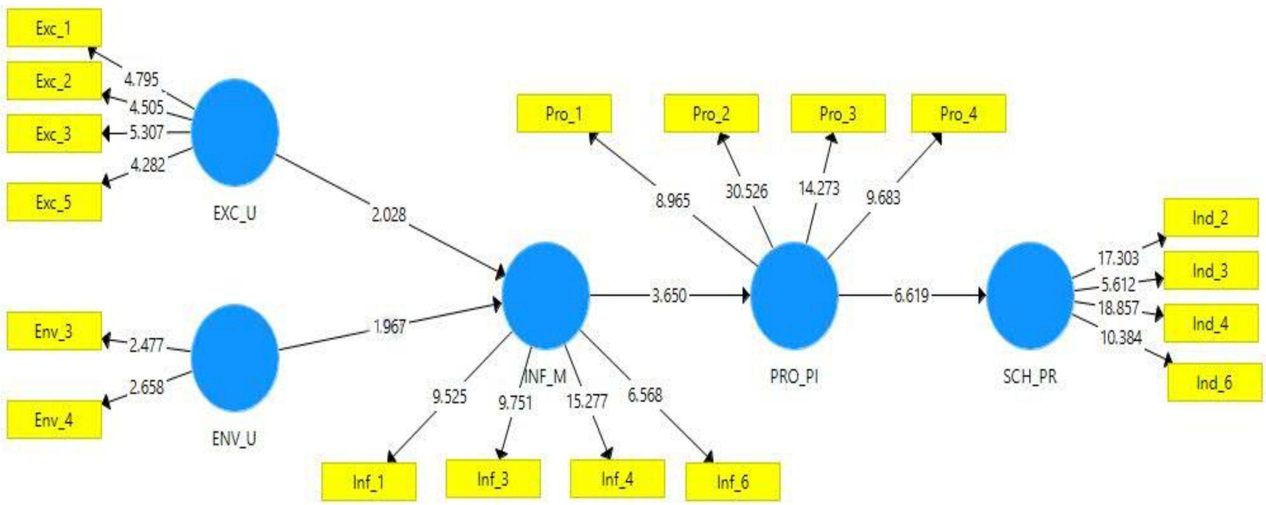


Figure 4.19 Structural Model (Bootstrap)

(44 Cases and 5000 re-samples)

(Planners: Scheduling of Process)

Added Relationships	Original sample	T-Statistics	P Values
Env_U → Inf_M	-0.142	1.967	0.028
Exc_U → Inf_M	-0.317	2.028	0.024
Inf_M → Pro_PI	0.484	3.650	0.000
Prd_PI → Sch_PER	0.573	6.619	0.000

Table 4.22 Added relationship (Planners: Scheduling of Process)

The results of the blindfolding for planners considering the scheduling of product as the performance criteria has been shown in the Table 4.33. All the value are above zero, therefore it can be concluded that has predictive accuracy.

Performance criteria	Cross validated redundancy	Cross validated communality
Influencing Measures	.045	.425
Product Performance Issues	.144	.430
Scheduling Performance	.188	.387

Table 4.23 Blindfolding Results (Planners: Scheduling of Process)

Importance-performance map analysis of the structural model was done check the importance and performance of different constructs by taking scheduling performance as the target constructs. The performance and importance map of constructs has been shown in the Figure 4.20 and performance- importance values for each construct has been tabulated in Table 4.24.

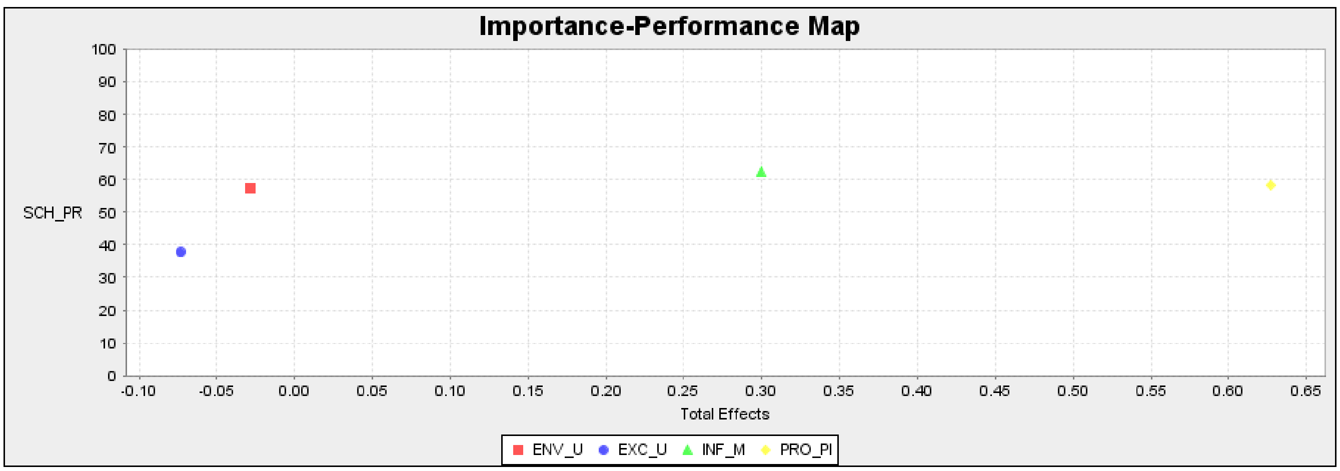


Figure 4.20 IPMA Map (Planners: Scheduling of Process)

Latent Variable	Importance	Performance
Sch_PR	Target	58.731
Pro_PI	0.6574	57.145
Inf_M	0.2958	62.395
Exc_Unc	-0.0742	37.405
Env_Unc	-0.0093	57.933

Table 4.24 IPMA Results (Planners: Scheduling of Process)

4.6 Summary of Results

This section summarizes the results which have been explained in this chapter. The results for the mangers and planners have been summarized separately.

4.6.1 Managers

The results reveal that the proposed model for scheduling of product criteria accounted for 37.9%, 60.7% and 33.9% of variances in scheduling performance, scheduling of product and influencing measures respectively. While proposed model for scheduling of process criteria accounted for 36.9%, 43.7% and 34.9% of variances in scheduling performance, scheduling of product and influencing measures respectively.

Overall, the results (Figure 4.21 and 4.22) support all of the hypotheses except for hypothesis 1a and 2a. The hypothesis 1a and 2a i.e. environmental uncertainty negatively effects Influential measures and the path coefficient and loadings between them have been 0.535, p = 0.128, T-statistic = 1.510 and 0.562, p = 0.136, T-statistic=1.495 for product and process criteria respectively. These results shows that the added relationship between the environmental uncertainty and influential measures has been positive and insignificant for both product and process criteria i.e. opposite of our assumption, hence the hypotheses 1a and 2a do not hold. The hypothesis 1b and 2b which indicates the relationship between executional uncertainty and influential measures have been found showing path coefficient and loadings have been,-0.594, p = 0.001, T-statistic = 3.486 and -0.567, p = 0.001, T-statistic = 3.412 for product and process criteria respectively, the results also shows that models are significant for both product and process, therefore the hypotheses 1b and 2b have been supported. The next hypothesis 1c i.e. influencing measure positively influence the scheduling of product with the path coefficient and loadings have been 0.779, p = 0.001, T- statistic = 13.550 as shown in Figure 4.21 has been found significant, hence hypothesis 1c is supported. In the same way, the hypothesis 2c i.e. influencing factors positively affects the scheduling of process, has been found significant as the path coefficient and loading for the relationship has been 0.661, p = 0.001, T-statistic = 7.593. Hence the hypothesis 2c has been supported. Subsequently, the hypothesis 1d between the scheduling of product and scheduling performance, which says that scheduling of product positively influences the scheduling performance has been found highly significant with path coefficient and loadings have been 0.582, p = 0.001, t statistic = 6.192 as shown in Figure 4.21. Hence the hypothesis 1d holds which means that the scheduling performance depends on the scheduling product. Similarly, hypothesis 2d, which says that scheduling of process positively affects the scheduling performance. The results shows that path coefficient and loading as 0.591, p = 0.001, T-statistic=6.658 (Figure 4.22). Hence the hypothesis 2d holds as well.

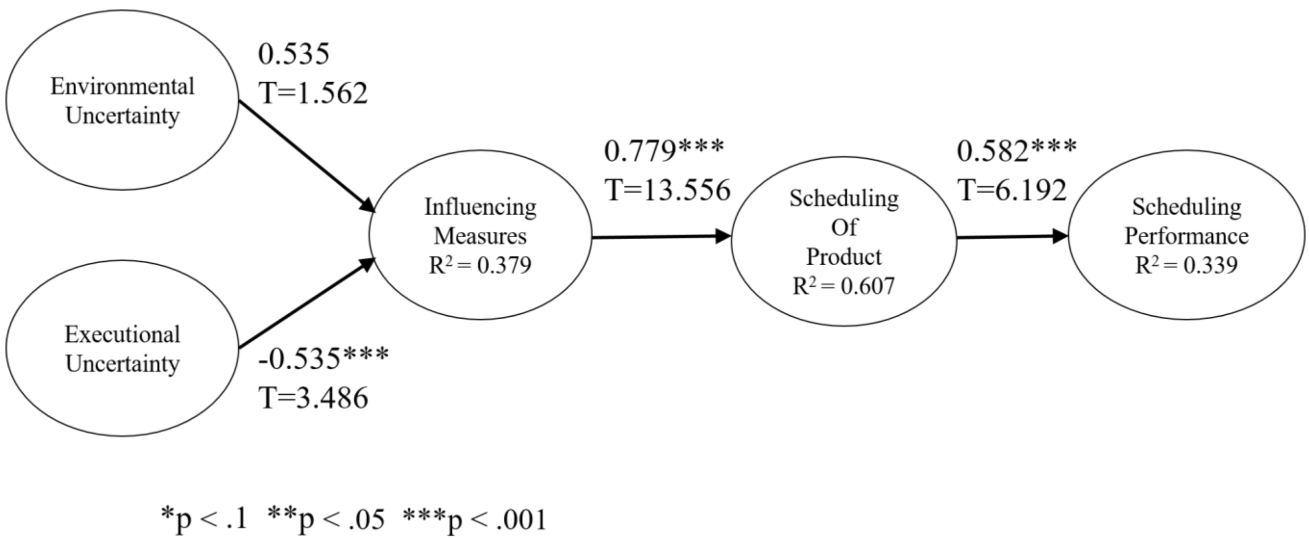


Figure 4.21 Path Model Results (Managers: Scheduling of Product)

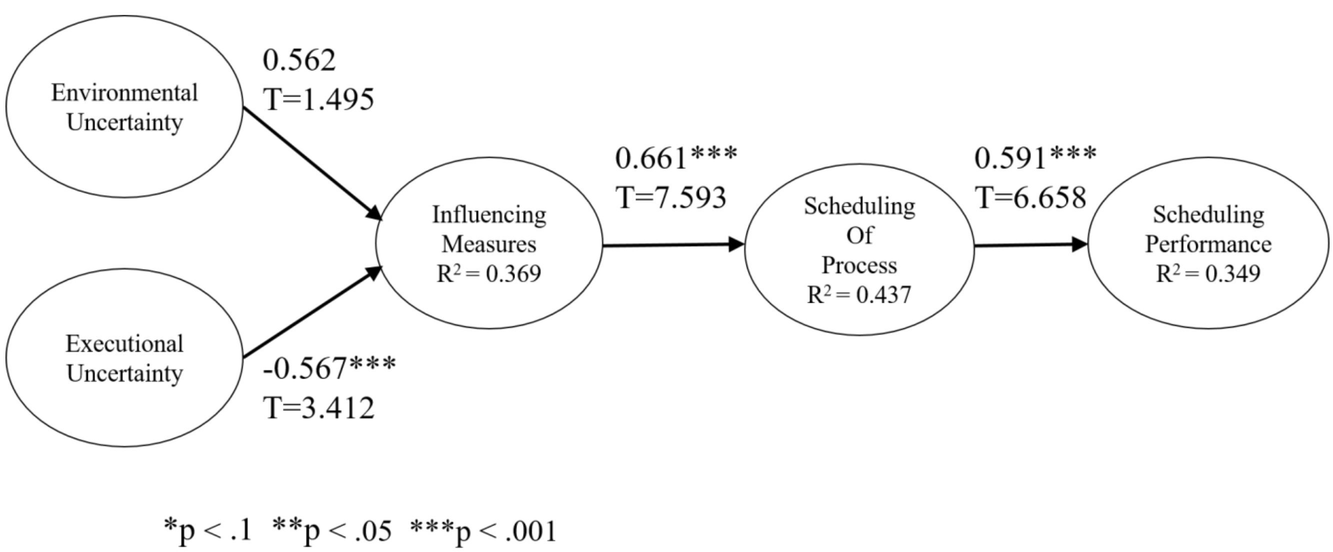


Figure 4.22 Path Model Results (Managers: Scheduling of Process)

As explained above, the hypotheses 1b, 1c, 1d (scheduling of product) and 2b, 2c, 2d (scheduling of process) have been supported, while the hypotheses 1a and 2a have not been supported from the managers point view as shown in the Table 4.24 . The significant effect of scheduling of product, scheduling of process and influential factors are similar to the findings of Snoo et al. (2011).

Hypothesis	T-value	Result
H1a: Env_U → Inf_M	1.510	Not supported
H1b: Exc_U → Inf_M	3.486	Supported
H1c: Inf_M → Prd_PI	13.550	Supported
H1d: Prd_PI → Sch_PER	6.192	Supported
H2a: Env_U → Inf_M	1.495	Supported
H2b: Exc_U → Inf_M	3.412	Supported
H2c: Inf_M → Pro_PI	7.593	Supported
H2d: Prd_PI → Sch_PER	6.658	Supported

Table 4.25 Summary of hypotheses testing: Managers

Subsequently, Importance-performance map analysis (IPMA) has been carried out to check the importance and the performance of different parameters on scheduling performance. IPMA has been performed by taking scheduling performance as the target construct and the effect of its predecessor constructs have been calculated. Table 4.11 and 4.14 shows the results for the product and process related criteria respectively. Both presents how the scheduling performance has been affected by the other constructs such as scheduling of product, scheduling of process, influential measures, environmental uncertainty, and executional uncertainty. The result shows that scheduling of product has been the most important and most performing construct, with the values of importance 0.6151 and .4785 for product and process criteria respectively. While influential factors have the importance value of 0.4041 and 0.3589 for product and process criteria respectively, therefore it can be improved so as to improve the target construct i.e. scheduling performance. The value executional uncertainty being the least important and the least performing construct negatively influence the scheduling performance for both product and process criteria.

4.6.2 Planner

The results reveal that the proposed model for scheduling of product criteria accounted for 32.9%, 23.4% and 10.1% of variances in scheduling performance, scheduling of product and influencing measures respectively. While proposed model for scheduling of process criteria accounted for 34.0%, 43.8% and 34.9% of variances in scheduling performance, scheduling of product and influencing measures respectively.

The overall results in Figure 4.23 and Figure 4.24 shows that all of the hypotheses for scheduling of product criteria and process related issues have been found correct. The hypothesis 3a and 4a which shows the relationship between environmental uncertainty and influencing measures for both product and process criteria have been showing negative path coefficient value. The path coefficient value and loading for hypothesis 3a and 4a has been -0.286, p = 0.05, T-statistic = 2.517 and -0.317, p = 0.05, T-statistic = 2.028 for product and process respectively. This means that environmental uncertainty significantly affects the influencing factors hence the hypothesis 1a and 2a have been supported. The hypotheses 3b and 4b have been showing path coefficient value and loading as, -0.210, p = 0.05, T-statistic = 1.968 and -0.142, p = 0.05, T-statistic = 1.967 for product and process respectively. Therefore the hypotheses 3b and 4b have also been supported, which means executional uncertainty which is significantly affecting the influencing factor is an important aspect of scheduling performance. The hypothesis 3c and 4c show the relationship between the influencing factors and the scheduling of product and process criteria respectively. The path coefficient and loading for hypothesis 3c have been 0.693, p = 0.001, T-statistic = 9.836 as shown in Figure 4.23 and path coefficient and loading for hypothesis 4c have been 0.484, p = 0.001, T-statistic = 3.650 as shown in Figure 4.24. As the relation between the influential factors and scheduling of product and process being an important one and has been found significant, therefore the hypothesis 3c and 4c has also been supported. The next hypothesis 3d says that scheduling of product positively influences the scheduling of product. The path coefficient and loading for the hypothesis have been 0.657, p = 0.001 T-statistic = 10.165. These values has been found to be have been found highly significant hence the hypothesis has been supported. Similarly the hypothesis 4d, which says that scheduling of process positively influences the scheduling performance has been found significant with path coefficient value and loading being 0.573, p = 0.001, T-statistic = 6.619.

As explained above, the hypotheses 3a, 3b, 3c, 3d and 4a, 4b, 4c, 4d for the scheduling of product and process respectively, has been supported as shown in Table 4.25.

Hypothesis	T-value	Result
H3a: Env_U → Inf_M	1.968	Supported
H3b: Exc_U → Inf_M	2.517	Supported
H3c: Inf_M → Prd_PI	9.837	Supported
H3d: Prd_PI → Sch_PER	10.165	Supported
H4a: Env_U → Inf_M	1.967	Supported
H4b: Exc_U → Inf_M	2.028	Supported
H4c: Inf_M → Pro_PI	3.650	Supported
H4d: Prd_PI → Sch_PER	6.619	Supported

Table 4.26 Summary of hypotheses testing: Planners

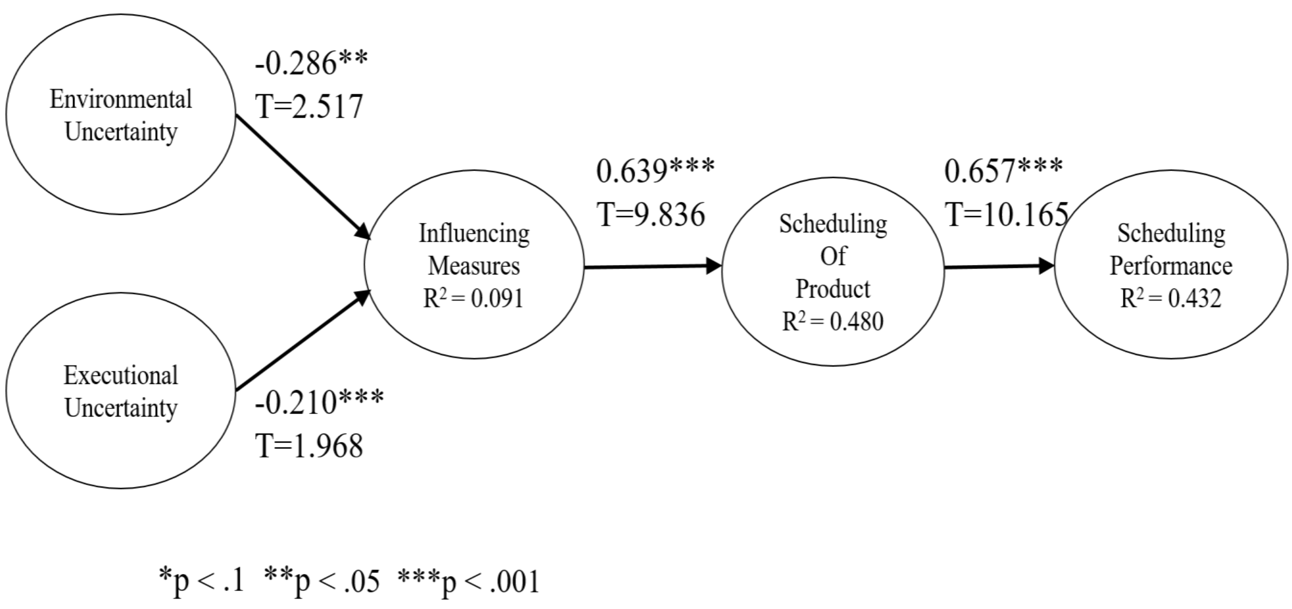
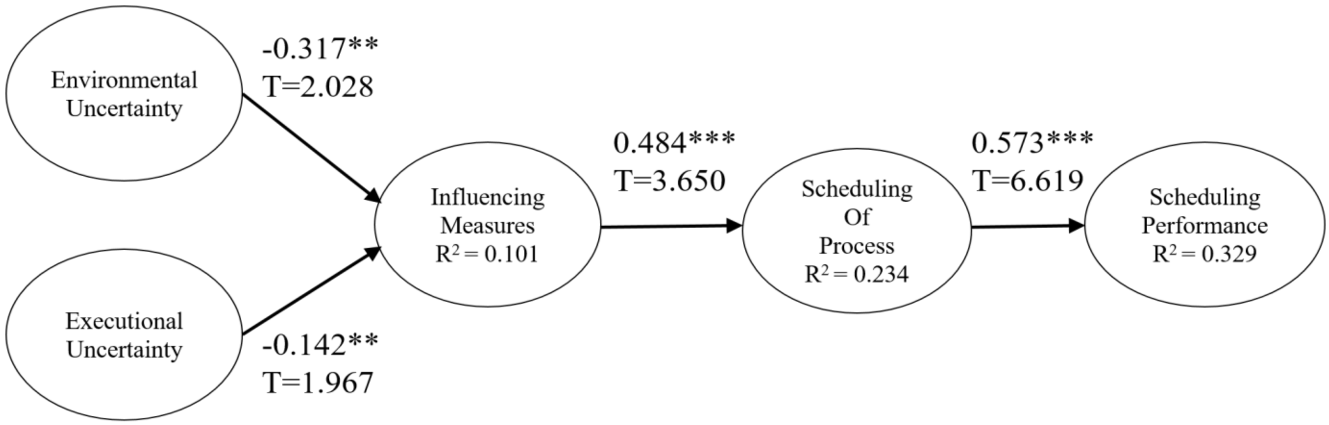


Figure 4.23 Path model (Planners: Scheduling of Product)



*p < .1 **p < .05 ***p < .001

Figure 4.24 Path Model (Planners: Scheduling of Process)

Importance-performance map analysis (IPMA) has been carried out to check the importance and the performance of different constructs on scheduling performance. IPMA has been performed by taking scheduling performance as the target construct and the effect of its predecessor constructs have been calculated. Table 4.21 and 4.24 shows the results for the product and process related criteria respectively for planners. Both presents how the scheduling performance has been affected by the other constructs such as scheduling of product, scheduling of process, influential measures, environmental uncertainty, and executional uncertainty. The result shows that scheduling of product has been the most important and most performing construct, with value of importance 0.7538 and 0.6574 for product and process criteria respectively. While influential factors have the importance value of 0.5017 and 0.2958 for product and process criteria respectively, therefore it can be improved so as to improve the target construct i.e. scheduling performance. The value executional uncertainty being the least important and the least performing construct and negatively influence the scheduling performance for both product and process criteria.

The study also shows that uncertainty as very important aspect while determining scheduling performance, executional uncertainty being more important than environmental uncertainty.

Chapter V

Discussion of Results

5.1 Discussion

As the process of identifying the criteria for scheduling performance is a complex task, therefore it becomes more necessary to have methods capable of handling more complex model structures. PLS-SEM proves to be really beneficial in this respect, as it allows estimating models with many constructs, structural model relationships and many indicators per construct, situations. The results of the SEM analysis has been discussed with respect to the current industry working conditions. In addition to those important findings from the study has been extracted. The results of manager and planner have been discussed separately in the next section.

5.1.1 Discussion of results: Managers

The empirical results revealed that both, scheduling of product and process criteria significantly affects the scheduling performance. The first relationship included variable (environmental uncertainty) acting on the variable (influential factors). The results revealed that environmental uncertainty, positively but insignificantly affects the influential factors for both product and process criteria of scheduling, which was hypothesized to be negatively affecting the influential factors. However, literature also suggests that environmental uncertainty negatively affects the planning and scheduling system. Johnson et al. (2005) argued that lack of information and unpredictability of the environmental variables adversely affect strategic planning in the South African IT industries and therefore negatively affect the planning system. Sabherwal et al. (1994) also concluded that environmental uncertainty have a negative effect on planning processes. The next relationship is between executional uncertainty and influential factors, the results revealed that executional uncertainty has been significantly and negatively affecting the influential factors which is in line with a previous research by Rasconi et al. (2010) which argues that executional uncertainty is a disruptive phenomenon hence negatively affect the scheduling process. This means that the executional uncertainty which is concerned with execution of schedule as intended, including disruption in production, shortage of raw material, etc. Snoo et al. (2011), must be minimal for smooth functioning of production system. Therefore the hypothesis for this relationship has been supported for both product and process criteria. The next relationship is between the influential factors and scheduling of product/process. The empirical results revealed that relationship of influential factors with scheduling of product and process are highly significant and positive, as hypothesized. This similar to the study of Snoo et al. (2011) which argues that influential factors which do not directly measures the scheduling performance but influence the process of scheduling performance measurement. Hence the hypothesis has been supported for both product and process criteria. Eventually, the relationship of scheduling product and process with scheduling performance have also been found highly significant and positive. The data in the study also reveals that scheduling of product is important than scheduling process in measuring the scheduling performance. Hence the hypothesis has been supported. Scheduling of product includes the measures such as correct job processing time, set up time, waiting time, adaptability, resource utilization, minimization of labor laws etc. Daniels et al. (1995), Hoogeveen (2005), Lokuge et al. (2006), Allahverdi et al. (2008) also confirms that measures of scheduling product plays an important role in measuring scheduling performance. Similarly, scheduling of process have also been found significant and positive, as hypothesized. Therefore the significant result strongly support the hypothesis. Scheduling of process included release of plan on time, accessibility of schedule, scheduler’s ability to collaborate and communicate with other departments etc. Berglunda and Karltun (2007) and Snoo et al. (2011) also supported this and also argued that these measures of scheduling process are extremely important in the predicting the scheduling performance.

5.1.2 Discussion of results: Planner

The empirical results revealed that all hypothesizes have been supported for both product and process criteria. The first hypothesis included the relationship between environmental uncertainty and influential factors. The results shows that environmental uncertainty significantly and negatively, as hypothesized affecting the influential factors for both product and process criteria of scheduling. These results are in line with previous research of Johnson et al. (2005) which argues that lack of information and unpredictability of the environmental variables adversely affect strategic planning in the South African IT industries and therefore negatively affect the planning system and Sabherwal et al. (1994) also presents the similar observation regarding the impact of environmental uncertainty on planning and scheduling system. Therefore the hypothesis in the study has been supported for both product and process criteria. The next relationship shows the impact of executional uncertainty on the influential factors. Executional uncertainty has been hypothesized to negatively affect the influential factors. The results shows that executional uncertainty has been significantly and negatively affecting the influential factors for both product and process criteria. These results have been supported by Rasconi et al. (2010), which also proved that high executional uncertainty can disrupt the planning and scheduling system. Hence this hypothesis has been supported for both product and process criteria. The next relationship is between the influential factors and scheduling of product/process. The empirical results revealed that relationship of influential factors with scheduling of product and process are positive (as hypothesized) and significant. This similar to the previous research of Snoo et al. (2011) which argues that influential factors which do not directly measures the scheduling performance but positively influence the process of scheduling performance measurement. Hence the hypothesis has been supported for both product and process criteria. The last relationship in the model shows the relationship of product/process criteria on scheduling performance. Empirical results revealed that both product and process criteria significantly and positively influence the scheduling performance, though it has been found that scheduling of product is more significant than scheduling of process. Scheduling of product included the measures such as correct job processing time, set up time, waiting time, adaptability, resource utilization, minimization of labor laws etc. Daniels et al. (1995), Hoogeveen (2005), Lokuge et al. (2006), Allahverdi et al. (2008) confirms that measures of scheduling product plays an important role in measuring scheduling performance. Likewise, scheduling of process which included release of plan on time, accessibility of schedule, scheduler's ability to collaborate and communicate with other departments etc. Berglunda and Karltun (2007) and Snoo et al. (2011) also confirmed that measures of scheduling process are extremely important in the predicting the scheduling performance.

Therefore it can be conclude that all the hypothesis has been supported except the relationship between environment uncertainty and influential factor for managers which has been found insignificant and opposite of what has been hypothesized.

Chapter VI

Conclusions

6.2 Limitation

While this study is important to understand key relationships of the product and process criteria of scheduling with scheduling performance and effect environmental and executional uncertainty on them in the Indian automobile industry, the study has some limitations.

This study was conducted in the medium and large scale automobile industries of northern India, study might end up with different results when it is applied in different atmosphere or type of industry. Therefore, we could not generalize the results of study to whole users in other geographical areas.

The study in thesis work has been concerned only with the medium and large scale automobile companies, hence results cannot be generalized for all types of industries.

The other limiting factor could be the sample size. Although 86 (44 from managers and 42 from planners) responses were received and were adequate for this study. However, a larger sample size may expose additional properties. The survey was sent to 60 companies out of which 35 responded, but it would have been better to send it to more to ensure the higher number of responses.

6.2 Conclusions

In today’s business environment scheduling performance has become a critical element for a production system to work efficiently. Firms are trying to adopt new approaches to improve the scheduling performance and manage the uncertainty in the system. Therefore, it is important to examine how the performance of scheduling can be measured and how uncertainty affects the scheduling performance. Our study focused on the critically examining the criteria of scheduling performance in Indian automobile industries.

The study in this research examined the measures for the criteria of scheduling performance such as product, process, and influential factors. The measure of executional and environmental uncertainty have also been examined. Separate studies have been conducted for planners and managers.

Results of our analysis revealed that both environmental and executional uncertainty has a negative impact on influential factors according to the planners, whereas manager's data shows that environmental uncertainty is positively affecting influential factor, though insignificant and executional uncertainty is negatively influencing the influencing factors. This shows disparity the opinion of the planner and manager, which can lead to problems in the production planning system. Therefore, need to be coherence in the opinion of planner and the mangers so as to ensure smooth functioning of the planning system.

The impact of influential factors has been positive on the scheduling of product and process for both managers and planners. The results reveals scheduling product and positively affects the scheduling performance for both planners and mangers, but the process criteria is more significant than scheduling of product according to the mangers while planners data reveals that scheduling of product is more significant than scheduling of process, which again shows the difference in the opinion of the planner and manager. The study also reports that measures such as schedule shifts fitting labor laws, releasing of the plan on time, increased schedulers knowledge and skill of schedulers, increased customer satisfaction are diverse scheduling criteria on which schedule should be evaluated. While the measures of scheduling which are particularly essential in the conditions with uncertainty are the frequency of feedback from the schedule user to the scheduler, frequency of new information delivered to the scheduler, rescheduling request received and frequency of rush orders observed.

Thus, the focus of the study has been to investigate the scheduling performance measurement criteria in the automobile companies in the northern India. These criteria have been added to the research model and the relationship amongst them has been evaluated. The study prominently showing the effect of uncertainty on the scheduling with respect to the Indian automobile industry.

6.3 Scope of future research work

The sample tested in our study is from the automotive industries in India and hence the results are general interpretation of automobile industries context and Indian environment. Further research is advised to study automobile industries or other types of industries from other countries, for better understanding and compare the results in a different environment.

In addition, the study examined the two main scheduling performance criteria, scheduling of product and process and effect of uncertainty on them has been analyzed. But, forecasting which is an important aspect of planning and scheduling has not been taken into consideration. Hence it can also be assessed for significance on scheduling performance.

Finally, based on this studies, considering the presented criteria for scheduling, which enables better reporting of performance information. Hence additional criteria for further improvement of scheduling performance can be developed in future research.

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Appendix A: Indicator Loadings in the model

Indicator	Description
Env_1	Frequency of rush orders observed
Env_2	Frequency of new information delivered to the scheduler(After the schedule has been released) is high
Env_3	Frequent delay in shipments from suppliers observed
Env_4	High frequency in transit delay observed
Exc_1	Execution of schedule has been delayed frequently
Exc_2	Schedule has not been executed as intended
Exc_3	Increase in slack time in schedule observed frequently
Exc_5	Requests for rescheduling received frequently
Inf_1	Correct estimation of job processing time
Inf_3	Fixing ownership of the scheduling process in the department
Inf_4	Updated data on production standards is available
Inf_5	Increased use of automated scheduling system(computer-based scheduling)
Inf_6	Increased scheduler's knowledge and skill
Prd_1	The schedule contains correct processing times
Prd_2	The scheduling contains correct production routings
Prd_3	Orders are delivered on time
Prd_4	Number of setup times are minimized
Prd_5	Number of waiting times are minimized
Prd_7	Schedule is easily adaptable
Prd_8	Scheduling shifts fit labor laws
Pro_1	The scheduler releases the plans in time.
Pro_2	The scheduler accommodates the rush order requests are promptly.
Pro_6	The scheduler communicates the finalized schedule to the stakeholders.
Pro_7	The scheduler does not micro manage operations at the shop floor.
Ind_1	Increased Satisfaction of clients
Ind_3	Fewer complaints from employees
Ind_5	Fewer inventory shortages or surpluses

Appendix B.1: Descriptive Analysis of data: Manager

A. Criteria focused on Scheduling of product

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Correct_Processing_Time	44	2	5	3.77	.774
Correct_Production_Routine	44	2	5	3.84	.861
Order_delivery_time	44	2	5	3.98	.762
Setup time minimized	44	2	5	3.70	.795
Waiting time minimized	44	2	5	3.59	.757
overtime minimized	44	1	5	3.70	.978
Easy adaptability	44	2	5	3.80	.795
Schedule fits labour laws	44	2	5	4.07	.900
Resource utilization realized	44	2	5	3.80	.878
Schedule within the financial budget	44	3	5	4.00	.647
Provides information about choices made by stakeholders	44	3	5	4.02	.792
Valid N (listwise)	44				

Table 1a Descriptive analysis: Scheduling of product

B. Criteria focused on Scheduling of process

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Release of plan on time	44	2	5	3.93	.925
Accomodation of rush order requests on time	44	2	5	3.84	.987
Scheduler easily accessible	44	1	5	3.64	.967
Scheduler collaborates with production,store and marketing etc	44	1	5	3.70	1.091
Scheduler balances stakeholders interst	44	1	5	3.45	.926
Schedulers communication with stakeholders	44	2	5	3.80	1.002
Schedulers micro management operations at the shop floor	44	1	5	3.20	.978
Valid N (listwise)	44				

Table 1b Descriptive analysis: Scheduling of process

C. Indirect Measures affecting Scheduling performance

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Increased satisfaction of clients	44	2	5	3.95	.714
Reduced absenteeism rates due to employee satisfaction	44	1	5	3.41	.972
Fewer complaints from employees	44	1	5	3.45	.951
Fewer production shifts in overtime mode	44	1	5	3.45	.999
Fewer inventory shortages or surpluses	44	1	5	3.57	.998
Fewer changes in the delivery dates of consignments	44	1	5	3.39	1.083
Valid N (listwise)	44				

Table 1c Descriptive analysis: Indirect Measures

D. Influential factors of scheduling performance

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Correct estimation of job processing time	44	2	5	3.80	.795
Reduced number of sources of information for making schedule	44	1	5	3.43	.998
Fixing ownership of the scheduling process in the department	44	2	5	3.75	.839
Updated data on production standards is available	44	2	5	3.89	.970
Increased use of automated scheduling system	44	2	5	3.91	.884
Increased scheduler's knowledge and skill	44	3	5	4.00	.807
Valid N (listwise)	44				

Table 1d Descriptive analysis: Influential Factors

E. Executional uncertainty in scheduling

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Execution of schedule has been delayed frequently	44	1	5	2.20	1.069
Schedule has not been executed as intended	44	1	5	2.16	1.033
Increase in slack time in schedule observed frequently	44	1	5	2.30	1.002
Frequency of feedback from the schedule user to the scheduler is high	44	1	5	3.09	1.030
Requests for rescheduling received frequently	44	1	5	2.75	1.144
Valid N (listwise)	44				

Table 1e Descriptive analysis: Executional uncertainty

F. Environmental uncertainty in scheduling

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Frequency of rush orders observed	44	1	5	2.64	.865
Frequency of new information delivered to the scheduler	44	1	5	3.20	1.112
Frequent delay in shipments from suppliers observed	44	1	5	2.57	1.065
High frequency in transit delay observed	44	1	5	2.45	1.088
Valid N (listwise)	44				

Table 1f Descriptive analysis: Executional uncertainty

Appendix B.2: Descriptive Analysis of data: Planner

A. Criteria focused on Scheduling of product

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Correct_Processing_Time	42	1	5	3.64	.958
Correct_Production_Routine	42	1	5	4.00	.855
Order_delivery_time	42	2	5	3.88	.916
Setup time minimized	42	2	5	3.86	.783
Waiting time minimized	42	2	5	3.64	.879
overtime minimized	42	2	5	3.81	.862
Easy adaptability	42	2	5	3.76	.850
Schedule fits labour laws	42	2	5	4.10	.878
Resource utilization realized	42	1	5	3.50	.890
Schedule within the financial budget	42	1	5	3.74	.798
Provides information about choices made by stakeholders	42	1	5	3.48	.917
Valid N (listwise)	42				

Table 2a Descriptive analysis: Scheduling of product

B. Criteria focused on Scheduling of process

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Release of plan on time	42	3	5	4.05	.731
Accomodation of rush order requests on time	42	2	5	3.86	.899
Scheduler easily accessible	42	3	5	4.02	.715
Scheduler collaborates with production,store and marketing etc	42	2	5	4.00	.937
Scheduler balances stakeholders interst	42	1	5	3.74	.798
Schedulers communication with stakeholders	42	2	5	3.93	1.113
Schedulers micro management operations at the shop floor	42	1	5	3.26	1.014
Valid N (listwise)	42				

Table 2b Descriptive analysis: Scheduling of process

C. Indirect Measures affecting Scheduling performance

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Increased satisfaction of clients	42	2	5	4.14	.783
Reduced absenteeism rates due to employee satisfaction	42	2	5	3.69	.950
Fewer complaints from employees	42	1	5	3.55	.968
Fewer production shifts in overtime mode	42	2	5	3.76	.932
Fewer inventory shortages or surpluses	42	1	5	3.79	.842
Fewer changes in the delivery dates of consignments	42	2	5	3.69	.950
Valid N (listwise)	42				

Table 2c Descriptive analysis: Indirect measures

D. Influential factors of scheduling performance

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Correct estimation of job processing time	42	2	5	3.64	.727
Reduced number of sources of information for making schedule	42	2	5	3.74	.828
Fixing ownership of the scheduling process in the department	42	1	5	3.62	.987
Updated data on production standards is available	42	1	5	3.69	1.093
Increased use of automated scheduling system	42	1	5	3.67	1.052
Increased scheduler's knowledge and skill	42	2	5	3.95	.764
Valid N (listwise)	42				

Table 2d Descriptive analysis: Influential factors

E. Executional uncertainty in scheduling

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Execution of schedule has been delayed frequently	42	1	4	2.31	1.047
Schedule has not been executed as intended	42	1	5	2.31	1.115
Increase in slack time in schedule observed frequently	42	1	5	2.26	.964
Frequency of feedback from the schedule user to the scheduler is high	42	1	5	3.31	1.158
Requests for rescheduling received frequently	42	1	5	2.67	1.119
Valid N (listwise)	42				

Table 2e Descriptive analysis: Executional Uncertainty

F. Environmental uncertainty in scheduling

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Frequency of rush orders observed	42	1	5	3.38	.909
Frequency of new information delivered to the scheduler	42	1	5	2.95	1.058
Frequent delay in shipments from suppliers observed	42	1	5	3.21	1.025
High frequency in transit delay observed	42	1	5	3.40	1.061
Valid N (listwise)	42				

Table 2f Descriptive analysis: Environmental Uncertainty

Appendix C: Questionnaire for the survey

Subject: Invite your application in research work related to scheduling performance

Dear Sir/Madam

I invite you to participate and provide useful inputs through the attached questionnaire developed to capture data/view on determinants of scheduling performance. This research is part of my master thesis at Thapar University, Patiala.

The study is an attempt to identify and establish criteria for scheduling performance in manufacturing industries in north India. The findings of the study would be published in all relevant forums.

I request you to take out 15 minutes of your precious time to fill out the questionnaire and send it back by Feb. 28th 2016. If you have any questions or clarifications about the study, please contact me at 9650309651/8725840232.

With warm regards

Yours Truly

Puneet Yadav

ME-Production Engineering

Thapar University, Patiala

Instructions

It will be appreciated if you answer to the best of your personal knowledge and experience .The information collected will be purely for academic purpose.

Please answer every question, and please check only one answer per question.

To complete the questionnaire:

i. Please use a BLUE or BLACK pen.
ii. Be sure to read all the answer choices before making your answer.
iii. Answer each question by placing a legible check mark or check mark in the box to the right answer, like this:

Extremely Important ✓

OR

Encircle answer that best suits your response, example 1 2 3 4 5

A	**Kindly provide the following information about your organization**		
	Please check in the appropriate box given below:		
	Organization Type:		
	i. Small Enterprise	☐	Industry Sector:
	ii. Medium Enterprise	☐	
	iii. Large Enterprise	☐	Department:
	iv. OEM	☐	
	v. First Tier Supplier	☐	Designation:
	vi. Second Tier Supplier	☐	
	vii. Third Tier Supplier	☐	

B	This section focuses on the **Product Performance Related Issues** in scheduling. Please indicate your choice based on the scheduling activity in your organization in the last one year.					
	Please indicate on a scale from 1 to 5 (1 indicates 'Not at all' and 5 indicates 'Most of all') the extent to which the following scheduling issues have been observed. (indicate by encircling in the appropriate column)	Not at all				Most of all
	i. The schedule contains correct processing times	1	2	3	4	5
	ii. The scheduling contains correct production routings	1	2	3	4	5
	iii. Orders are delivered on time	1	2	3	4	5
	iv. Number of setup times are minimized	1	2	3	4	5
	v. Number of waiting times are minimized	1	2	3	4	5
	vi. Overtime is minimized	1	2	3	4	5
	vii. Schedule is easily adaptable	1	2	3	4	5
	viii. Scheduling shifts fit labor laws	1	2	3	4	5
	ix. Resource utilization rates are realized (No Shortages or No Surpluses)	1	2	3	4	5
	x. Schedule remains within financial budgets	1	2	3	4	5
	xi. Schedule provides information about choices made by all the stakeholders	1	2	3	4	5
C	This section focuses on the **Process Performance Related Issues** in scheduling. Please indicate your choice based on the scheduling activity in your organization in the last one year.					
	Please indicate on a scale from 1 to 5 (1 indicates 'Not at all' and 5 indicates 'Most of all') the extent to which the following scheduling issues are observed. (indicate by encircling in the appropriate column)	Not at all				Most of all
	i. The scheduler releases the plans in time	1	2	3	4	5
	ii. The scheduler accommodates the rush order requests are promptly	1	2	3	4	5
	iii. The scheduler is easily accessible to renegotiate schedule constraints (example - due dates, routing, rush order)	1	2	3	4	5
	iv. The scheduler collaborates with Production, Stores and Marketing for finalizing the schedule	1	2	3	4	5

	v.	The scheduler balances the stakeholders interests in finalizing the schedule	1	2	3	4	5
	vi.	The scheduler communicates the finalized schedule to the stakeholders	1	2	3	4	5
	vii.	The scheduler does not micro manage operations at the shop floor	1	2	3	4	5
D	This section focuses on the **Indirect measures** of scheduling performance. Please indicate your choice based on the scheduling activity in your organization in the last one year.						
	Please indicate on a scale from 1 to 5 (1 indicates 'Not at all' and 5 indicates 'Most of all') the extent to which the following scheduling issues are observed. (indicate by encircling in the appropriate column) Not at all ↔ Most of all						
	i.	Increased Satisfaction of clients	1	2	3	4	5
	ii.	Reduced absenteeism rates dues to employee satisfaction with the schedules	1	2	3	4	5
	iii.	Fewer complaints from employees	1	2	3	4	5
	iv.	Fewer production shifts in overtime mode	1	2	3	4	5
	v.	Fewer inventory shortages or surpluses	1	2	3	4	5
	vi.	Fewer changes in the delivery dates of consignments	1	2	3	4	5
E	This section focuses on the **Influencing factors** of scheduling performance. Please indicate your choice based on the scheduling activity in your organization in the last one year						
	Please indicate on a scale from 1 to 5 (1 indicates 'Not at all' and 5 indicates 'Most of all') the extent to which the following factors influence the scheduling performance. (indicate by encircling in the appropriate column) Not at all ↔ Most of all						
	i.	Correct estimation of job processing time	1	2	3	4	5
	ii.	Reduced number of sources of information for making schedule	1	2	3	4	5
	iii.	Fixing ownership of the scheduling process in the department	1	2	3	4	5
	iv.	Updated data on production standards is available	1	2	3	4	5
	v.	Increased use of automated scheduling system(computer-based scheduling)	1	2	3	4	5
	vi.	Increased scheduler's knowledge and skill	1	2	3	4	5
F	This section focuses on the **Executional Uncertainty** in scheduling. Please indicate your choice based on the scheduling activity in your organization in the last one year. Executional uncertainty concerns uncertainty in the schedule execution process that prevents the schedule being executed exactly as intended.						
	Please indicate on a scale from 1 to 5 (1 indicates 'Not at all' and 5 indicates 'Most of all') the extent to which the following scheduling issues are observed. (indicate by encircling in the appropriate column) Not at all ↔ Most of all						
	i.	Execution of schedule has been delayed frequently	1	2	3	4	5
	ii.	Schedule has not been executed as intended	1	2	3	4	5
	iii.	Increase in slack time in schedule observed frequently	1	2	3	4	5

			1	2	3	4	5
	iv.	Frequency of feedback from the schedule user to the scheduler is high	1	2	3	4	5
	v.	Requests for rescheduling received frequently	1	2	3	4	5
G	This section focuses on the **Environmental Uncertainty** in scheduling. Please indicate your choice based on the scheduling activity in your organization in the last one year. Environmental Uncertainty concerns with changing information about what has to be scheduled, and about the constraints of to be taken into account.						
	Please indicate on a scale from 1 to 5 (1 indicates 'Not at all' and 5 indicates 'Most of all') the extent to which the following scheduling issues have been observed. (indicate by encircling in the appropriate column) Not at all Most of all						
	i.	Frequency of rush orders observed	1	2	3	4	5
	ii.	Frequency of new information delivered to the scheduler(After the schedule has been released) is high	1	2	3	4	5
	iii.	Frequent delay in shipments from suppliers observed	1	2	3	4	5
	iv.	High frequency in transit delay observed	1	2	3	4	5
H	This section specifically focuses on the response mode adopted in dealing with the uncertainty in scheduling.						
	Please indicate on a scale from 1 to 5 (1 indicates 'Not at all' and 5 indicates 'Most of all') the extent to which the following scheduling issues have been observed. (indicate by encircling in the appropriate column) Not at all Most of all						
	i.	If executional uncertainty is high quick response is preferred	1	2	3	4	5
	ii.	If executional uncertainty is low optimized response is preferred	1	2	3	4	5
	iii.	If environmental uncertainty is high quick response is preferred	1	2	3	4	5
	iv.	If environmental uncertainty is low optimized response is preferred	1	2	3	4	5

I	**Kindly provide the your personal information**	
	Name:	
	Address:	
	Contact No. :	Signature/Stamp

Appendix D: List of companies participated in the survey

S.No	Name of the company	Address
1	Diesel Locomotive Modernization Workshop	Patiala, India
2	Rail Coach Factory	Hussainpur, Kapurthala, Punjab
3	Goodyear India Ltd	Goodyear India Ltd; Mathura Road, Ballabgarh; Distt, Faridabad – 121004; Haryana
4	International Tractors Ltd.	Rm Town, Railway Road, Hoshiarpur, Punjab
5	Prakash automotive industries (p) ltd	Indra Complex,tigaon road, Faridabad, Haryana
6	JBM Auto Ltd.	Plot No. 5, Sector - 31. Kasna Industrial Area, *Greater Noida UP*
7	Jay bharat maruti Ltd.	Plot No. 5, Joint venture complex, Udyog Vihar Phase IV, Sector 18, Gurgaon, Haryana
7	Jay bharat maruti Ltd.	Sector 36, Mohammadpur Jharsa, Khandsa, Near Hero Honda chowk, Gurgaon, Haryana
8	Jay bharat maruti Ltd.	Maruti Joint Venture, Sector 8, IMT Manesar, Gurgaon, Haryana
9	SKH Metals Ltd	Plot No.2, Maruti Joint Venture Complex, Gurgaon, Haryana
10	SKH Metals Ltd	Plot No.1, (13&24), MSIL Supplier Park, Phase-3A, IMT Manesar, Gurgaon-122050, Haryana
11	Caparo Maruti Ltd	Plot No.7, Maruti JV Complex, Delhi - Gurgaon Road, Gurgaon, Haryana
12	Gmax Auto Ltd	Plot no:-33,Sec-5, Phase-2 Industrial Growth Center, Industrial Model Twp, Bawal, Haryana

13	Sona Steering Systems Limited	38/6, NH-8, Institutional Area, Delhi-Jaipur Road, Gurgaon, Haryana
14	Sandhar Technologies Limited	Plot no 3 & 4, HSIDC Industrial Area, Sector-18, Old Delhi-*Gurgaon* Road, *Gurgaon*, Haryana
15	Sandhar Technologies Limited	Village - Dhumaspur, P.O. - Badshahpur, Sohna - Gurgaon Road, Gurgaon Haryana
16	Keihin fie pvt Ltd	Plot no- 81-83 & 94-96, sec-6, HSIIDC growth Center, Bawal, Haryana
17	AG Industries Private Limited	Plot No. GP-9, Sector-18, Gurgaon, Haryana
18	Continental Automotive Brake Systems India Pvt. Ltd	Plot No.179-180 Sector 5, IMT Manesar, Gurgaon, Haryana
19	Bharat seats Ltd.	Plot No. 1 Maruti Udyog Joint Venture Complex Palam, Gurgaon Road Gurgaon
20	Rico auto industries Ltd.	38,Km Stone, Delhi - Jaipur Expressway, Gurgaon, Haryana
21	Rico auto industries Ltd.	69 Km Stone Dharuhera Haryana
22	Mark Exhaust Systems Ltd	39/7, Begumpur Khatola, N H-8, Delhi Jaipur Highway, Gurgaon, Haryana
23	SKH SMC Ltd	Plot No.2, Maruti Joint Venture Complex, Gurgaon, Haryana
24	Fcc clutch India private Ltd	Plot 5, Sector 3, IMT Manesar, Gurgaon, Haryana
25	Neel Metal Products Ltd.	Pace City II, Sector 36, Gurgaon, Haryana
26	Bellsonica auto component india pvt Ltd	Plot No. 1, Phase3A, Sector 8, IMT Manesar, Gurgaon, Haryana
27	Hema Engineering Industries Ltd	1/3, K M Khandsa Road, Gurgaon, Haryana
28	APL Apollo tubes Ltd.	A-19, Industrial Area, Sikandrabad, District - Bulandshahar, U.P.
29	Sandhar han sung technologies private Ltd	Village & Post Khandsa, Behrampur Road, Gurgaon, Haryana

30	Sandhar Tooling Pvt. Ltd	Plot No. 92, Sector 3, IMT Manesar, Gurgaon, Haryana
31	Neel Metal Products Ltd.	Plot No. 12 Sector 5 Manesar Gurgaon, Haryana
32	Sharda Motor Industries Ltd.	India Steel Limited, Kasana, Greater Noida, Uttar Pradesh
33	GRAZIANO Trsnsmissioni India Pvt. Ltd	Plot No., Udyog Kendra Greater Noida, UP
34	Lumax DK Auto Industries Ltd.	Plot no. 165, Sector 5 IMT Manesar Gurgaon
35	Amtek Siccardi India Limited	Plot 54, Sector 3, Manesar, Industrial Model Township, Manesar, Gurgaon, Haryana