ABSTRACT

The hierarchical production planning and control has been disputed since the early 1990s and a paradigm shift has emerged that highlights the role of humans in controlling job shops. However, most approaches to supply chain management still follow the conventional hierarchical approach, which establishes the interaction between supply partners at the management control level and does not consider decisional role for shopfloor control level.

This study challenges this viewpoint. It discusses human contribution to collaborative supply-chain planning and scheduling within automotive industry. The development and execution of plans in a car manufacturing group and its suppliers are discussed. The research methodology involves an analysis of qualitative data from an ethnographic field study on planning and scheduling practices.

Two scenarios of collaborative scheduling are analysed through which it is shown how the operational levels adapt their own strategies to cope with operational variations. The management control systems do not receive detailed information of what happens. They receive aggregate reports of non-conformances during the execution for which they develop compensatory plans and send them to the task control level and the story repeats from the beginning.

Keywords

Collaborative Planning and Scheduling, Human Factors, Supply Chain Management, Automotive Industry

INTRODUCTION

The traditional view of hierarchical production planning and control, as exemplified by Anthony (1965), perceives operational control (or task control) as not requiring skill and judgment. Shopfloor jobs are presumed to be repetitive: essentially the following of instructions. The decision process and information flow is taken as top-down. Shopfloor personnel are seen to implement instructions formed through decisions made at higher levels of the organisation.

By the mid 1980s, a group of studies were published that focussed on the planning and control of production at the shopfloor level. While there had been significant advances in methods within operations research (OR) and artificial intelligence (AI) that produced promising improvements in production planning, scheduling and control, these techniques could not cope with dynamic characteristics within manufacturing (McKay et al., 1988). AI systems once implemented, often remained
in use for only a limited time, before changes to the manufacturing environment rendered their underlying construct problematic (Pinedo and Seshadri, 2001). Under rapidly changing conditions in technology and operational uncertainty, which were becoming prevalent characteristics of the business environment, decision-making by human planners and schedulers are paramount. How to support planning and scheduling by humans with decision support systems (DSSs) became a theme of research (Wiers, 1997a; 1997b). Higgins and Wirth (1995) went beyond traditional DSSs and developed a model for hybrid intelligence systems that fused intelligent human behaviour and AI techniques through a visual interface that supported humans in applying constraint-based reasoning.

Human aspects of planning and scheduling evolved into a semi-mature field of research from early 1990s nascency through late 1990s puberty. It received a fillip in 2004, with the establishment of HOPS (Human and Organisational factors in industrial Planning, Scheduling, and Control) funded by COST (the European Cooperation in the field of Scientific and Technical research). HOPS has provided an avenue for collaboration between groups through frequent meetings and workshops, and by organising special sessions at conferences. This stimulus aside, researching the role of humans in inter-organisational relationships in supply chain management is but in its infancy.

Since the 1980s, rapid advancements in information and communication technologies have changed the boundaries of business. The ‘local service society’ has become the ‘global mobile knowledge society’. Now, technically diverse organisations commonly work together. Their collective work may spread geographically among firms markedly different in size and business objectives. Planning, scheduling, and control of production and distribution depend on the goals, roles and activities of players and resources. All may change dynamically and some may be unspecified or uncertain. Nevertheless, organisations do collaborate in coordinating activities for their mutual benefit. How to use collaborative resources wisely for a competitive advantage becomes the key question (Harvey and Koubek, 2000)?

Collaboration in scheduling across organisations entails many changing parameters, high degrees of uncertainty and ill-defined information. Group decision-making is distributed and involves multiple criteria associated with goals that may be in conflict. Potential solutions to problems that arise depend on the specificity of problems, the state and dynamics of the system. Grappling with incomplete knowledge of the problem space, players strive to define and implement solutions. Moreover, the multiple stakeholders may have difficulty in developing a feasible solution within a reasonable time. Instead, they apply a partial solution that moves the system towards the desired state. Such problems, classified as wicked, are only understood as solutions develop. The problem definition and solution co-evolve (Rittel and Webber, 1973). Consequently, they are not well-suited to software solutions, as these tend towards brittleness.

The common view of collaborative planning and scheduling follows a hierarchical structure that is similar to Anthony’s (1965) description but across organisations. With alliances, joint ventures, and other forms of associations between organisations, collaboration starts with top-level agreements. Subsequently, defining strategies and tactics are the provinces of management control. Standard descriptions of organisational relations do not extend to hierarchical descriptions of the interactions between organisations. It is assumed that planning and scheduling activities across organisations occur between the decision centres of each organisation. The level of task control merely carries out higher-level decisions and contributes nothing to collaborative planning and scheduling. Anthony and Govindarajan (1995) clearly state the role of task (operational) control is mechanistic because of its scientific nature: “In management control, managers interact with other managers, in task control, either human beings are not involved at all (as is the case with some automated production processes), or the interaction is between a manager and a non-manager.” From this perspective, shopfloor personnel, who deal with task control, do not make decisions through liaison with non-managers. The inference that follows for supply-chain planning and control is
that all relationships between organisations occur at the level of management control and none at the operational level. There is no role for shopfloor experts in collaborative planning and scheduling. This leads to a focus on management control and organisational units in supply-chain relationships. This viewpoint underpins models of Supply Chain Management, the formation of ISO standards, operational research techniques and business models. The reality is to the contrary.

Observational field studies show that persons at the operational level do not deal solely with their managers. Rather, many formal procedures of management control are never implemented. The field study presented in this paper shows plans and schedules never realised. Their development and distribution are for political and competitive expediency.

Humans within organisations contact one another at the level of task control. Semi-formal and informal networks abound. They are important under conditions where uncertainty is high and disruptions are many. It is neither efficient nor practical for operational staff to double-check every change to production plans with higher-level managers. Even if they do so, they must handle situations as they arise. Therefore, they adapt their strategies to cope with variances in the system. Then again, management control systems do not receive details on instances. They receive aggregate reports of non-conformances during execution. They develop compensatory plans for task control.

The aim of this case study is to explore the contributions by operational people in collaborative planning and scheduling across the supply chain. The case study looks at the automotive industry and examines what happens to the decisions made by the management control systems when executed by the operational staff.

**STUDIES ON HUMAN COLLECTIVE WORK**

There have been few studies on the interaction of human planners and schedulers across supply chains. A study by Jackson (2003) concerns the interaction between human, organisational, and the elements of the information systems of an operations management system. She developed a framework for analysing socio-technical systems associated with the planning and scheduling of supply chains with eleven functions as components. They include processes and information systems in supply chain planning, data analysis, communication of information, management of plan, decision making, monitoring environment, interpersonal communication, meetings, roles and responsibilities, tasks and activities.

Windischer and Grote (2003) investigated collaborative planning across supply chains. They focus on success factors in collaborative planning processes, the main problems hindering a joint optimisation, and helpful conditions. They describe the requirements for coordination of inter-organisational logistics for the management of uncertainties. They use these requirements to examine how companies design their logistic processes and compare the extent of information exchange for different supply chains. They elaborate a model for analysis of collaborative planning processes, which is then used to scrutinise how individuals successfully relate their logistic processes to each other. Based on their analysis, simultaneity of autonomy and coupling was found to be a key requirement of inter-organisational coordination, in which degree and type of division of labour affect the coordination mechanisms. They employ Action Regulation theory for describing coordination in which planning is conceived as an important element of goal-directed action. Actions are seen as units of work activity that are hierarchically and sequentially organised. Concomitantly, collaborative planning requires flexibility.

Dani et al. (2003) consider the human aspects of supply-chain optimisation from a behavioural perspective. They model the relationships between individuals in supply-chain networks. They employ transactional analysis to explore opportunistic behaviours leading to win-lose situations and hence reduction in trust. They model interactions between the individuals and organisations in games, which have been identified and observed in these relationships. They observe a variety of games that include collaboration, collusion, loss leader, and jostling for advantage. Their work
shows the importance of power. The more powerful member generally sets the rules and controls the game. It highlights the wise use of power in eliminating of games. That is because much of the transaction patterns appear to be means of acquiring power in the transaction process primarily to leverage the maximum value for the organisation (Dani et al., 2003).

Akkermans et al. (2004) highlight the duality of information transparency and trust for successful collaborative supply chains. Trust develops through habituation: forming habits and institutionalising behaviour. Trust builds at multiple organisational levels through a cycle of trust, communication and habituation. The assertion that trust is essential for collaboration between organisations is at the heart of our automotive case study.

CASE STUDY

The case study consists of collaborative plan development and maintenance between the following participants in a joint initiative of machinery development:

1. IKO\(^1\) – a large-scale vehicle-manufacturing group that aims to develop its production lines with a focus on automation and robotic flexible manufacturing systems
2. PSEY – a technology supplier that is a sister company to one of the world’s automotive giants located in another country
3. TAM – a general contractor, specialising in advanced manufacturing technology for the automotive industry.

Structure and process of planning and scheduling

The development projects in the TAM-IKO-PSEY joint initiative have five levels of decision-making relating to planning and scheduling:

1. **Executive Committee**: responsible for strategic, long-term and high-level decisions and management of new products and contracts, prices, etc., it consists of the CEOs of PSEY and IKO, and also includes for some projects the CEO of TAM.
2. **Management Committee**: responsible for mid-term decision-making and management for projects (e.g., approval of Master Plan, developing plans for strategic decisions, problem solving in critical cases), it consists of the senior planners, managers of IKO, TAM and PSEY.
3. **Management Task Force**: responsible for decision-making in project master management (e.g., preparing Master Plan, project’s progress reports, related Action Plans, controlling related teams’ progress, reporting to Management Committee), it consists of the project managers of IKO, TAM and PSEY.
4. **Technical Task Force**: responsible for decision-making related to executive teams in projects relating to sub-plan management. (e.g., progress reports, defining and pursuing Action Plans, reporting to Management Task Force), it consists of the executive stakeholders from PSEY, TAM, IKO, and other main suppliers and subcontractors.
5. **Suppliers Executive Teams**: responsible for decision-making in details of operation execution in projects based on sub-plans, and it consists of suppliers’ representatives.

A top-level agreement between senior managers of the collaborating companies triggers the formation of a high-level Management Committee. It consists of senior representatives of each company who have the authority to make decisions regarding the project, and representatives of other stakeholders, such as governmental authorities and shareholders. The Management Committee defines

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\(^1\) Being commercial-in-confidence, for this case study, pseudonyms are applied to not identify supply chain participants.
projects for a ten-year horizon. The first step in planning a project is to define it technically. This provides an environment for developing a common ground between the parties, a necessary foundation for sharing knowledge. The first-level plan covers the purpose of the project, main activities, job sharing, major timing and important dates. In generating the plan, the committee creates common shared information relating to resources, abilities and limitations. Each project includes a master plan and several sub plans. The master plan lists general activities in the project, its milestones and the project’s Gateways. Each project is divided into specific time segments, which are called Gateways. Management Committee develops this plan in the start of the project. Initially, there are only a few timelines based on the experience of IKO and PSEY, which come from history records, which are used to define major milestones. In phase one, the major milestones for the master plan are defined. The Master Plan is the official plan for all stakeholders that includes general agreements that cannot changed unilaterally by any party. The sub plans, developed by task-force teams, are detailed plans that accord with the master plan. Figure 1 illustrates this process.

Each task force meets weekly to review progress. Problems that cannot be resolved within a task force are considered by a biweekly meeting of the leaders of all task forces. Problems which they are unable to resolve are forwarded to the Project Manager.

Every week, each task force informs the project office of the status of activities using a standard form for WBS (Work Breakdown Structure)\(^2\). The project officers aggregate this information in a report for the project manager. For problem resolution and decision-making, the project manager meets the task force leaders in biweekly meetings to resolve issues regarding activities that have been delayed, postponed or undetermined. Consequently, action plans are developed for critical activities. Where the project manager, acting in consort with the task force leaders, cannot develop an action plan, the issue is passed to the Management Committee for a decision. They must deal with all issues that require a modification to the Master Plan.

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\(^2\) Work Breakdown Structure (WBS): an exhaustive, hierarchical from general to specific, tree structure of deliverables and tasks that need to be performed to complete a project.
RESEARCH DESIGN

This case study applies a grounded theory approach and consists of the following steps: data collection, open coding, axial coding, focused coding and pattern matching, and grounding the analysis. Data collection comprises gathering qualitative and quantitative data on collaborative planning and scheduling. It includes conducting interviews with different parties of the supply chain, collecting manuals and instructions, plans and schedules for the last two years, phone and email communications, in addition to reports, field notes, tools, and documents used in plants.

Open coding performs intensive line-by-line process of the interview transcripts.
This is to reveal the theoretical possibilities in the data. It remains open to what can be seen in the data at the first glance, no matter these are relevant or irrelevant to the original research question. It is important that the open coding does not use pre-established codes. In the meantime, it is important to make sure that particular themes and explicit and implicit categories in the data are understood (Esterberg, 2002). To encoding transcripts, the analysis employs Protocol Analysis. The aim is to identify the important aspects of the domain, for example, the concepts, attributes, tasks and relationships. Open coding consists of two steps in the case study. In the first step, relevant and important information in the interview transcripts are encoded. This step selects those sentences that contain significant data. The second step consists of reading the interview transcripts in the database in detail and assigning open codes to them. This step uses open coding approach as mentioned above.

Axial coding aims for finding connections and recurrent themes between abstract codes found in the open coding stage, through a process in which categories identified at the stage of open coding are refined, developed and related. The interconnection between the open codes is achieved during iterative rounds. Some relational concepts might emerge in the first round. However, by finishing the coding, some other concepts and themes appear to be important. Moreover, open codes might be classified in more than one themes. To avoid letting conceptual themes to mislead the axial codes, major open codes in the protocol analysis are first identified. The next step is to find interrelations between these major codes. This relationship can be first expressed by interconnection of codes. Therefore, for each of the major codes, other connected codes are identified. A cross-analysis will reveal those connected open codes that are common in each transcript.

Focused coding investigates data again and looks for more abstract categories and themes. Pattern matching and comparison is where the results of the analysis are congregated together and are looked at using a previously-developed model of collaborative scheduling and information processing (c.f., Nezamirad, 2004; 2005). Focused coding stage shares with open coding line-by-line reading of the interview transcripts, however, this time evidences for the core category are sought.

**Data verification and grounding the analysis**

Data verification stage needs to examine the results against the data. Design of this analysis of NBT case study minimises the effects of the common pitfalls that might happen during the research (Esterberg, 2002): a) first impressions tend to have more intensity than later ones; coincidental concurrent events might mislead people to infer relations that do not exist; and the information might not be reliable. To avoid these pitfalls this research employs two strategies during the whole process: triangulation and confirmation.

Triangulation concerns the use of multiple sources in the case study (Yin, 1994; Denzin, 1978). Triangulation broadens range of historical, attitudinal, and behavioural issues during case studies and allows for development of converging lines of inquiry (Yin, 1994). In the IKO case study, two types of triangulations mentioned by Yin (1994) and Patton (1987) are adopted into the research design: data triangulation and investigator triangulation. Data triangulation employs multiple sources for data. It includes interviews from different people as well as different geographical areas. Investigator triangulation concerns the use of different interviewers and data collectors in data collection stage. An important factor in this strategy is to keep in consistency of the study while triangulation on investigators.

The results of the case study are checked for confirmation in three stages. First stage occurs when the researchers return the interview transcripts back to the interviewees to confirm recorded information with data sources. The second type of confirmation occurs between researchers, when they double check results of the analysis. Third stage is checking the result of the study by winery staff, where they modify and/or confirm the correct interpretation of data and grounding the analysis.
ANALYSING HUMAN CONTRIBUTION

TAM schedulers deal with two levels of stakeholders: the management task force and the suppliers’ schedulers. For the 139 companies that work with TAM, schedulers need to coordinate their plans with this supply network in a way that the requirements of the project’s Master Plan are satisfied. This paper studies two scenarios of interaction between operational people across the supply chain and their impacts on the collaborative work.

The first set of interactions occurs between TAM and PSEY schedulers. Their common goals are summarised in the master plan. Both have expressed their goals through their representatives in the management committee. However, because of so many reasons, the master plan cannot be implemented as it has been developed. It will significantly change due to dynamic nature of the environment. This happens, for example during production of turntables, when the PSEY scheduler introduces some goals that have not been declared beforehand because of competitive agenda or lack of information. For example, their commitments to other clients are delayed and hence for compensating those delays, the TAM schedule is amended. The PSEY scheduler can also alter the condition when they re-adjust their schedule in managing disruptions. Inaccurate estimate for design duration is also a source of uncertainty that affects the schedule when it comes to the later stages.

These amendments imply new conditions to TAM reflecting on their schedule. Therefore, TAM operational staff have to re-adjust the schedule based on the new restrictions. Moreover, they change the conditions when making installation decisions based on both quality considerations and operational issues relating to equipment availability. Therefore, TAM operational personnel are also following up their amended goals in changing conditions. The following excerpts from the interviews address the problems in execution when conditions are disturbed.

"Sometimes we may have booked for a set of turntables to come in. But, we may get on the same day a cancellation when our QA representative visits the company, which could be postponed by a week sometimes. Sometimes a QA man may visit on a day which is 4 days prior to the due date and may make a decision to bring forward the due date."

The main problem relates to the fact that it is not clear what changes in the network of operations may influence which other part of the network. No one has adequate control over the actual restrictions on other parts of the supply network. Some iterative feedbacks happen when, for example, a supplier cannot meet the requested schedule. However, it is not clear to what extend this really feeds back to TAM or whether the required changes to the planned schedule would be significant enough to really affect the monthly schedule.

Furthermore, a significant issue is that the schedule is never executed exactly as planned. In practice, there are frequent disruptions in carrying out the operations and changes to the schedule are almost always handled by the operational staff rather than by any of the scheduling staff. It cannot be expected that these staff have an appropriate overview of the whole supply network to understand wider ramifications of the decision they need to make on the spot. The following statements summarise the problem.

"All of us think we have everything we need in our office to do our work in our own company, but the problem arises when we need to change and reschedule an activity. To make a correct decision, it seems everybody needs to know everything at that stage. Once we solve a problem with one of our suppliers, we will have problem with others’ schedules. Although we try to consider all relevant activities, the amount of rework we produce by our solutions is not less than the workload produced by unavoidable changes."

Non-conformances between the implemented and planned activities would then be reported to the higher levels of the hierarchy. These reports use aggregated
information and hardly transform the real information of what reasons have been involved. Furthermore, personal considerations on individual performance are highly influential in the abstracted information sent to the high-level management. The managers, then, far from the source and reasons for the disruptions, revise the project plan and send it to the operational staff.

The second set of interaction happens between schedulers in TAM and its suppliers. Because TAM is a manufacturing contractor, it outsources projects in separated sub-projects to manufacturers and suppliers. For this purpose suppliers’ schedulers prepare proposed schedule for the sub-project based on the information charted in the master plan, their knowledge of the work, and previous similar projects. Proposed plans are then sent to the TAM scheduler from different suppliers. The TAM scheduler’s task is to combine all the proposed schedules and make one schedule out of them. This schedule incorporates supplier selection, sub-project allocation, and timing. Therefore, the proposed schedules play a critical role as if the suppliers are bidding for the sub-projects. Of course, price and quality are also vital issues in supplier selection. Nonetheless, for a set of fairly comparable quality and price, the time frame becomes critical. As a result, proposing plans for sub-projects turns to be competitive amongst the suppliers. Every scheduler tends to make a better plan and consequently, some unreal information is included as the schedulers intend to use optimistic timelines and overbidden capacities. They send proposals demanding more activities than they capacity and propose shorter completion times than they are able to offer.

In effect, suppliers fail to consider TAM’s goals to have real information to prepare a smooth schedule for the project. The reason for this ignorance is manyfold. There is a tendency in suppliers for competing on projects. They also might be unaware of the relevant information from the TAMS’s side as well as other suppliers. Another reason relates to over- or underestimation of activities. For any reason that it happens, the ignorance of the TAM’s goals would result in unrealistic information by which decision-making is not promising. This fact causes proposed plans to be more official-good-looking but less practicable in the field. It produces a virtual level of plans that goes around the supply chain nevertheless is not real. The TAM scheduler then uses these proposals in their discussions with PSEY and IKO on the master plan, and subsequently, the virtual information flies across the higher levels of supply chain. This problem reinforces the bullwhip effect in the collective work (Nienhaus et al., 2003; Lee et al., 1997). Surprisingly

**CONCLUDING DISCUSSION**

A case study on collaborative planning and scheduling in automotive supply chain is concisely presented in this paper. Four main stakeholders are a vehicle-making group, a general contractor, a technology supplier, and manufacturing suppliers. They coordinate activities towards a common goal: production development. Meanwhile, each one targets its own goal throughout this collaboration. The car manufacturer is looking for a smooth production. The technology supplier is after delivering designs and documents at the best time and format to maximise their revenue according to agreements. The contractor would like to utilise their capacity. Manufacturing suppliers are looking for more projects, with less cost, and maximum revenue. The question is how these goals are met during collaborative work, in particular, how the planning function influence goal achievement for each party.

A paradigm shift in job shop scheduling has emerged since early 1990s (McKay et al., 1995). It contests traditional hierarchical production planning and control and underlines the role of human experts in handling uncertain situation and disruption management at shopfloor level.

However, the above paradigm shift has not yet happened at the inter-organisational level. Most approaches to supply chain management follow the traditional hierarchical view supposing that the management control levels at the participative organisations are main connection points. According to this perspective, task control (operational) level consists of human operators who are
working with either machines or their managers. Hence, there is no judgement at this level. As a result, supply chain coordination occurs in interaction between management levels. They set common and individual goals and make plans, which will be convincingly implemented in practice.

This paper challenges this viewpoint. In fact, field observations demonstrate the existence of relational networks at the operational level across supply chains that are actually controlling operations and coordinating activities. An observational case study in automotive industry is presented in this paper. The substantial difference between organisational, official plans and field occurrence sparks off the investigation of authentic coordination point in supply chains. Master plans are supposed to play a coordinating role between organisations. However, during the process, operational schedules do not necessarily comply with (and even use) the master plans. Are managerial decisions (stated in master plans) the eventual coordination point between organisations, or the operational levels (supervisors, field dispatchers, and shop floor schedulers) control relationships across the supply chain?

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