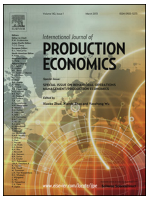
Int. J. Production Economics 176 (2016) 69–81

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe



The impact of organizational culture on Concurrent Engineering, Design-for-Safety, and product safety performance

Andy Yunlong Zhu [a], Max von Zedtwitz [b,*], Dimitris Assimakopoulos [c], Kiran Fernandes [d]

[a] Goodbaby International Holdings Limited, No. 20 Luxi Road, Lujia Town, Kunshan City, Jiangsu 215331, PR China
[b] GLORAD Center for Global R&D and Innovation, School of Economics and Business, Kaunas University of Technology, Gedimino 50 – 414, LT-44239 Kaunas, Lithuania
[c] EM LYON Business School, 23 Avenue Guy de Collongue, CS40203, 69134 Ecully Cedex, France
[d] Durham University, Durham University Business School, Durham DH7 9RH, United Kingdom

ARTICLE INFO

Article history:
Received 22 December 2014
Received in revised form
13 March 2016
Accepted 15 March 2016
Available online 23 March 2016

Keywords:
Organizational culture
New product development
Product safety
Innovation
Concurrent Engineering
Design-for-Safety
Performance

ABSTRACT

This paper empirically extends the research on the relationships between organizational culture, new product development (NPD) practices, and product safety performance (PSP). Using Schein's conceptualization of culture (i.e., underlying assumptions, espoused values, and artifacts), we build and test a model among five variables: top management commitment to safety (MCS), group level product safety culture (PSC) at NPD, Concurrent Engineering (CE), Design-for-Safety (DFS), and product safety performance. We propose that the underlying assumption of safety first affects the espoused values (group level product safety culture at NPD) and artifacts of organizational culture (Concurrent Engineering and Design-for-Safety); espoused value influences artifacts; and artifacts impact product safety performance. These hypotheses are tested by structural analyses of 255 survey responses collected from 126 firms in the juvenile product sector. While management commitment to safety, product safety culture, and Design-for-Safety are significant product safety predictors, as expected, Concurrent Engineering has no significant direct effect on product safety. We discuss the implications of these findings for the field of product safety.

1. Introduction

Product safety is a matter of enormous economic and societal concern. The U.S. Consumer Product Safety Commission (CPSC) estimates that in the United States alone, “deaths, injuries and property damage from consumer product incidents cost [the US] more than $1 trillion annually” (CPSC, 2009). Hundreds of millions of consumer products are recalled every year for safety risk reasons, and the financial risks to individual firms are significant, too: White and Pomponi (2003) estimated the average cost to manufacturers for every recall at about $8 million. For example, General Motors recalled 28 million cars worldwide due to faulty ignition switches in 2014 at a cost estimated in the billions of dollars (Popper, 2014). At the very least, sub-par product safety and product recalls tarnish a manufacturer's reputation and damage product brands.

There is overwhelming research that shows product safety is largely determined by how well a firm controls its NPD process: approximately 70% of product recalls have been traced to shortcomings in product development (Beamish and Bapuji, 2008; White and Pomponi, 2003). Our paper empirically examines the impact of NPD on product safety. We add to the pertinent literature on product safety in three aspects:

1) Product safety and its relationship with NPD. Most empirical studies on product safety focus on technical aspects and overlook the effect of product safety on culture (Abbott and Tyler, 1997; Main and Frantz, 1994; Main and McMurphy, 1998; Moller and Hansson, 2008; Wang and Ruxton, 1997). Much of the literature on this topic appears to be anecdotal and prescriptive.
2) Product safety performance rather than general product quality. Only a handful of studies on NPD include product safety when measuring product quality (Koufteros et al., 2001, 2002; Koufteros and Marcoulides, 2006; Sethi, 2000). Product safety has never been included as an independent variable, and product safety management practices and tools are not explicitly explored in any of the studies on NPD and product quality (Calantone and Benedetto, 1988; McDonough, 2000; Millson and Wilemon, 2008; Rusinko, 1997; Song et al., 1997; Song and Parry, 1997; Tatikonda and Montoya-Weiss, 2001), although

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* Correspondence to: GLORAD, Inst. for Techn. Management, University of St. Gallen, Dufourstrasse 40a, CH-9000 St. Gallen, Switzerland.
E-mail addresses: andyzhuyl@yahoo.com.sg (A.Y. Zhu), max@post.harvard.edu (M. von Zedtwitz), da@em-lyon.com (D. Assimakopoulos), k.j.fernandes@durham.ac.uk (K. Fernandes).

http://dx.doi.org/10.1016/j.ijpe.2016.03.007
0925-5273/

some (e.g., Fynes and De Búrca, 2005) have considered conformance quality (design quality, conformance quality, external quality-in-use, product cost, time-to-market and customer satisfaction) and customer complaints as measures of product quality performance.

3) Product safety and NPD in the context of organizational culture. Only a few studies have investigated the relationship between organizational product safety culture and product safety (European Commission, 2008; Svenson, 1984; White and Pomponi, 2003) both from theoretical discourse and industry best practice.

Earlier work using Schein's (1992) conceptualization of culture (e.g., Koufteros et al., 2007; Nahm et al., 2004; Yauch and Steudel, 2002) evaluated the effects of organizational culture on manufacturing practices and firm performance. Extending this conceptualization of culture, we test a model among five variables: (1) top management commitment to safety, (2) group level product safety culture at NPD, (3) Concurrent Engineering, (4) Design-for-Safety, and (5) product safety performance. We investigate the assumption that improvements in those five key variables lead to better product safety performance.

Our empirical analysis is based on an individual-level survey of product category/business unit perceptions of 255 NPD quality and engineering directors sampled from 126 firms in the juvenile product sector. The results from this research, as well as its managerial and theoretical implications, are intended to help managers further improve product safety through the design of better NPD processes and guide researchers towards better explanatory models about product safety and innovation. The following section includes theory development, key hypotheses, and an explanation of data collection methods and model analysis. After the discussion of the main findings, we draw conclusions and propose implications for theory and management practice.

2. Theory development

2.1. Organizational culture

Organizational culture has been researched for decades (Deal and Kenney, 1982; Hofstede, 1997; Schein, 1992). A fundamental difference in understanding culture is whether to focus on the way people think or the way people behave (Cooper, 2000), and one of the most well-known behavior/practice definitions for organizational culture is “the way we do things around here” (Deal and Kenney, 1982, p. 4). Hofstede (1997, pp. 182–183) concluded that “shared perceptions of daily practices should be considered to be the core of an organization's culture.”

In a comprehensive definition, Schein (1992) summarized organizational culture as a set of observed behavioral regularities, group norms, espoused values, formal philosophy, rules of the game, climate, embedded skills, habits of thinking, share meanings, and root metaphors. He aggregated these into three levels: (1) artifacts, (2) espoused values, and (3) underlying assumptions. At the surface, there are observable artifacts that one sees, hears, and feels when one enters an organization (e.g., organizational structures, policies, procedures, processes, practices, rituals, language, etc.). At the second level, there are espoused values (e.g., norms, ideologies, philosophies, strategies, and goals) that govern behaviors and explain why members behave the way they do. The third level of the hierarchy is composed of underlying assumptions, such as preconscious, taken-for-granted, and invisible beliefs that determine perceptions, thought processes, feelings, and behavior.

2.2. Underlying assumptions

Organizational culture and organizational structure are interrelated, according to Harrison (1972) and Handy (1976). As this paper's purpose is to evaluate how organizational culture and NPD practices affect product safety performance, we map how various components of a company's product development system represent those artifacts, values, and assumptions as defined by Schein (1992).

Top management plays a critical role in establishing company culture (Hofstede, 1997) and in setting the tone of product safety and establishing a safety-oriented culture (Eads and Reuter, 1983; Roland and Moriarty, 1983), especially through top-level commitment in all matters related to product safety, establishing priorities, policies and procedures, and allocating dedicated resources. Other indicators of safety-oriented culture can be found in the formulation of Key Performance Indicators (KPIs) and the review of safety performance and evaluation of individual attitudes towards safety (International Nuclear Safety Advisory Group, INSAG, 1991). White and Pomponi (2003) found that the highest performers integrated safety, regulatory, environmental, and health initiatives into their corporate strategy and articulated specific goals for each area. Given the significant moral and legal risks for top managers, their views and beliefs on what constitutes a safety-oriented culture transcends all layers of an organization and requires full, genuine, and constant commitment by its company leaders (Ryan, 2003). We therefore posit that top management's commitment to safety (i.e., how product safety is perceived and positioned) is one of the manifestations of the underlying assumptions in organizational culture in the context of product safety, and is consistent with Hofstede's (1997) view of top management's involvement in defining organizational culture.

2.3. Espoused values

An organization's underlying assumptions give rise to what Schein (1992) called a company’s espoused values: common beliefs shared by the members of an organization about “what ought to be” rather than “what is”—the domain of artifacts. Such a set of values also exists in the context of an organization’s attitude towards product safety. A strong organizational “safety first” philosophy impacts members’ beliefs and attitudes towards product safety, and consequently, leads to its high priority and adoption of processes and practices that support the organization's commitment to product safety. Moreover, this espousal of occupational health and safety culture has been linked to safer work behaviors (Hofmann and Stetzer, 1996; Varon and Mattila, 2000) and fewer employee injuries (Barling et al., 2002; Hofmann and Stetzer, 1996; Mearns et al., 2003; Zohar, 1980).

The literature on product safety culture is still sparse. Svenson (1984) made one of the earliest contributions when he studied Volvo's accident hazard management system and the general quality and product safety attitude of its technicians. Focusing on business safety measures in the toy industry, the European Commission (2008) echoed the importance of a strong quality and product safety culture. This is especially critical in design organizations (Rollenhagen, 2010).

While the literature emphasizes the value of a strong product safety culture, it is unclear how a product safety culture influences activities and practices in NPD. Consequently, we define group level Product Safety Culture as product safety related beliefs, norms, and values shared by the employees involved in NPD to determine how they act and react during product development in relation to product safety.

2.4. Artifacts

Artifacts are the tangible expressions of organizational culture—the technologies, organizational structures and functions, systems, and processes that make up an organization—and they are critical in the day-to-day operation of firms. In the context of product safety and product development, we focus on Concurrent Engineering and Design-for-Safety as key artifacts and processes in NPD that are both governed by espoused values and underlying assumptions.

2.4.1. Concurrent Engineering

In contrast with the conventional, sequential "throw it over the wall" approach, CE requires all representatives from functions such as manufacturing, design, quality, and purchasing, including suppliers and customers, to work together simultaneously, although at sometimes varying degrees, throughout the NPD process (Dekkers et al., 2013). CE is characterized by three main components: the cross-functional team, concurrent work-flows (or overlap), and the early involvement of participants (Koufteros et al., 2001).

The effect of CE on product quality is inconclusive (Koufteros et al., 2002; Koufteros and Marcoulides, 2006; McDonough, 2000; Ragatz et al., 2002; Rusinko, 1997; Sethi, 2000; Tatikonda and Montoya-Weiss, 2001). Clark and Fujimoto (1991) were among the first to demonstrate that CE used in incremental projects not only reduces product development cycle time but also decreases product quality. However, Rusinko (1997) described a positive effect on product quality by both organizational-level and group-level design-manufacturing integration, and McDonough (2000) found the use of cross-functional teams significantly related to team performance, including developing high quality products. Tatikonda and Montoya-Weiss (2001) showed that process concurrency, formality, and adaptability (all of them organizational process factors) have a positive effect on product quality, cost, and time-to-market.

Regarding the effects of CE on product safety, scholars and practitioners alike suggest that safety engineers should be involved in product design as early as possible and recommend using CE (Dowlatshahi, 2001; Wang and Ruxton, 1997; Rausand and Utne, 2008). However, the analytical and empirical evidence for this claim is still weak primarily because product safety has never been examined as a standalone variable. Even if product safety is included as one aspect of product quality, the literature is inconclusive on whether a positive relationship exists between product quality and CE. For instance, Sethi (2000) revealed that quality is positively influenced by information integration in the team, customers' influence on product development process, and quality orientation in the firm, but it is negatively affected by the innovativeness of the product. Sethi did not find functional diversity to have any effect on product quality. Measuring product quality in terms of function, safety, reliability, durability and performance, Koufteros et al. (2001) found that CE has a positive direct relationship with product innovation, but they did not find any significant direct relationship between CE and quality. In a later paper focusing on NPD practices, Koufteros et al. (2002) reported CE has a positive impact on quality, a result that Koufteros and Marcoulides (2006) qualified by demonstrating that this effect is mediated by high versus low cellular manufacturing environments.

Thus, although the literature on the interrelationship of CE, product quality and NPD is growing, the impact of CE on product safety has not been evaluated empirically.

2.4.2. Design-for-Safety

NPD systems and processes are the primary tools to implement product-oriented safety culture and innovation. A well-defined, high-quality NPD process is generally recognized as a critical success factor for product success (Cooper et al., 2004; Montoya-Weiss and Calantone, 1994) and product quality (Calantone and Benedetto, 1988; Millson and Wilemon, 2008; Song et al., 1997). However, whether the use of certain technical activities and methodologies in the NPD process affects product quality positively is less clear. According to Calantone and Benedetto (1988), product quality is influenced by technical activities such as preliminary engineering, technical and manufacturing review, prototyping, in-house product testing and trial production, and, as Millson and Wilemon (2008) asserted, especially by technical activities in the early stages of the NPD process. Fynes and De Búrca (2005) found that design quality has an impact on conformance quality, product cost, external quality-in-use, and time-to-market. However, Song et al. (1997) did not find any significant direct relationship between technical proficiency and product quality.

DFS encompasses the procedures, methodologies, and practices that a company implements in NPD to manage product safety, with a focus on the technical and engineering aspects such as safety factors, hazard analysis, and safety management tools. DFS studies have increased given a large percentage of accidents and incidents are rooted in design (Kinnersley and Roelen, 2007). Although there is substantial support for methodologies integrating safety into the design process (Drogoul et al., 2007; Fadier and De la Garza, 2006; Hasan et al., 2003; Rausand and Utne, 2008; Schulte et al., 2008), the challenge is to identify all the relevant hazards given the increasing complexity of technology, products, and systems and to meet the safety objective under the trade-off decision between cost, schedule, and performance (Rausand and Utne, 2008).

The effective use of safety management tools, such as Faulty Tree Analysis (FTA), Preliminary Hazard Analysis (PHA), and Failure Mode Effect Analysis (FMEA) is important in managing integration in the NPD process (Abbott and Tyler, 1997; Nelson & Eubanks, 2005). Riswadkar (2000) also pointed out that Hazard Analysis and Critical Control Point (HACCP), a systematic approach to food safety, can be applied to other products and processes. However, most design engineers do not receive formal training in safety methodologies (such as FTA and FMEA) common to the safety community, and many product safety tools are not systematically implemented by the design community (Main and Frantz, 1994; Main and McMurphy, 1998). Safety management tools and DFS are considered important, but the effectiveness of hazard analysis is still unclear (Marucheck et al., 2011).

Even though the literature has identified a high quality NPD process as a key success factor for NPD, its implications for product safety remain unknown at best because safety management methodologies and product safety performance are not well understood. A thorough conceptual understanding of how Design-for-Safety practices affect product safety (rather than just product quality) is still largely missing.

2.5. Product safety performance

Following Daughety and Reinganum (1995) and the European Union Directive 2001/95/EU Article 2(b) (European Union Directive, 2002), product safety has been defined as whether the operation or use of a product under normal or reasonably foreseeable condition of use, including duration, involves risk of injury or damage to health of users or damage to property or environment. A product is considered safe if the risk involved is considered acceptable and consistent with a high level of protection for the health and safety of consumers.

In most cases, product safety performance information is confidential and not available to the public, and it has been measured in diverse ways in different studies depending on the availability of data, e.g. using recall rates for consumer products (White and Pomponi, 2003) or accident and incident rates in the airline industry (Rose, 1990). Measuring product safety performance is difficult because objective accident data are insufficiently sensitive, of dubious accuracy, retrospective, ignore risk exposure (Glendon and Litherland, 2001), and tend to be very unstable (DeJoy et al., 2004; Havold, 2005).

In conclusion, we assign the following concepts to parameters as follows:

1. Management Commitment to Safety, respectively, "safety first," is an underlying assumption in organizational culture. We study its effect on espoused values.
2. Product Safety Culture is part of espoused values (i.e., the firm's values, beliefs, perceptions, and attitudes towards product safety). We study product safety culture at the level of NPD, with variables addressing issues such as whether the NPD team members consider product safety more important than cost and schedule, whether the product safety review team is independent from NPD engineers, and whether NPD engineers understand safety requirements and consider these requirements in their daily work. We expect effects on visible artifacts in NPD.
3. We consider NPD practices such as Concurrent Engineering and Design-for-Safety as visible artifacts.

3. Hypotheses

The importance of visionary leadership and top management on firm culture, activities, and performance is well established (Hofstede, 1997; Ogbonna and Harris, 2000; Schein, 1992). Although many activities critical to product safety (such as CE, DFS, and also more generally, NPD processes and strategies) are not part of top management's primary responsibility, management commitment directly and indirectly influences attitudes and process (in organizational culture terminology: values and artifacts) that promote a positive safety-oriented culture using specific safety-inducing incentives (Eads and Reuter, 1983; Roland and Moriarty, 1983; White and Pomponi, 2003), and lead to higher product safety performance. The extent to which top management supports quality affects management perceptions (Benson et al., 1991), and product safety performance is higher in firms with a product safety strategy with demonstrated senior leadership and a commitment of resources to implement safety, regulatory, environmental, and health management practices (White and Pomponi, 2003).

What is still unclear, however, is how many of these product-safety oriented values and artifacts influence each other in mediating the overall influence of top management commitment on product safety performance. Much of the established literature on these important links is anecdotal or prescriptive, and there is little empirical research on how management commitment to safety translates into practices and affects product safety.

Management commitment to safety and management's role in establishing a product safety culture are also important for NPD more directly affecting product safety. DFS and CE strengthen operational product innovation efficiency, but they also create well-tested and safe products (Dowlatshahi, 2001; Rausand and Utne, 2008; Wang and Ruxton, 1997). DFS's specific focus on safety and CE's shared intra-functional design practices should encourage management to commit resources and implement well-defined NPD techniques with more predictable outcomes. However, management's ability to establish any of these attributes of organizational culture (Garvin, 1987; Schein, 1992) may vary significantly between the two direct NPD artifacts of DFS and CE. In summary, the following hypotheses are proposed:

H1. Management Commitment to Safety has a positive effect on Product Safety Culture in NPD.

H2. Management Commitment to Safety has a positive effect on Concurrent Engineering.

H3. Management Commitment to Safety has a positive effect on Design-for-Safety.

Safety culture, safe work behaviors, and safety performance have received scholarly attention since the term safety culture first appeared in the 1987 OECD Nuclear Agency report (INSAG, 1988). However, most research focused on occupational health and safety; only a handful of studies looked at product safety culture. In an example of early research, Svenson (1984) identified employees' positive safety attitudes as a critical success factor of accident hazard management systems. Van Vuuren (2000) found safety culture had a considerable impact on both incident causation and risk management and concluded the traditional focus on human and technological failure should be replaced by a comprehensive approach that includes organizational and cultural precursors. Similarly, White and Pomponi (2003) found firms with a safety-oriented culture had better product safety performance, an insight echoed by a report by the European Commission (2008), which stated that a strong quality and safety culture were a critical element in ensuring continuous attention to product safety issues.

A strong product safety culture in NPD centers more on safety methodologies (such as hazard analysis, FMEA) and better executed or more disciplined NPD and CE processes, which may lead to excessive risk aversion, passed down to NPD via stricter tolerances and safer work practices, which result in safe but also less differentiated products. The new products might meet minimal innovation specifications and safety criteria, so perfect safety may only be achievable through absolute reliance on standard rather than novel solutions and through expensive zero-fault testing. However, this approach is not always economically viable for firms; internal mechanisms and processes such as CE and DFS are intermediary instruments to achieve predictable product success, of which product safety is a component outcome. Those firm values supporting a culture favoring product safety also have an effect on NPD techniques, such as CE and DFS, which leads to the proposition of the following hypotheses:

H4. Product Safety Culture in NPD has a positive effect on Concurrent Engineering.

H5. Product Safety Culture in NPD has a positive effect on Design-for-Safety.

CE techniques are used not only to speed up innovation and NPD but also require otherwise separate teams (for different functions, disciplines, or components) to coordinate themselves better, communicate product and process-related issues, and address problems relating to product safety performance promptly. CE interaction regarding product design questions are bound to address safety concerns; however, in the multi-functional context of CE, these issues should receive more rounded and integrated consideration, and if so, we would expect DFS to improve with greater emphasis of CE in NPD. Hence, we propose the following hypotheses:

H6. Concurrent Engineering has a positive effect on Design-for-Safety.

H7. Concurrent Engineering has a positive effect on Product Safety

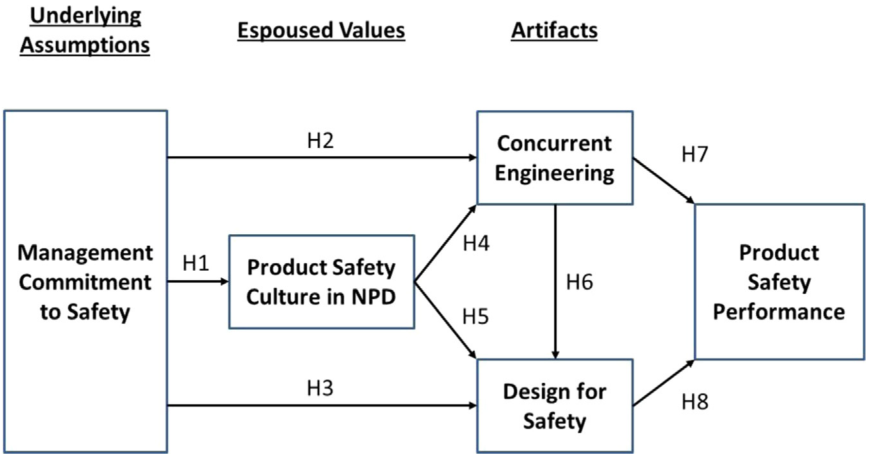

Fig. 1. Research framework.

Table 1
Demographics of the sample: 255 respondents from 126 firms.

Respondents	**Position of respondents**	**No. of responses (%)**
	Quality manager/director, senior quality engineer	201 (78.8%)
	Engineering manager/director	30 (11.8%)
	Product managers	8 (3.1%)
	GM/VP	16 (6.3%)
	Total	255 (100%)
Firm size	**N=No. of employees**	**No. of responses (%)**
	$N<500$	29 (11.4%)
	$5000>N\geq$ 500	123 (48.2%)
	$N>5000$	103 (40.4%)
R&D intensity	**R=Ratio of R&D expenses/sales**	**No. of responses (%)**
	$R<3\%$	116 (45.5%)
	$R\geq 3\%$	139 (54.5%)
Firm ownership	**Location**	**No. of firms (%)**
	Chinese firms or JV in China	90 (71.4%)
	Overseas firms located in USA, EU, JP, NL, AU	36 (28.6%)
	Total	126 (100%)

Performance.

Design-for-Safety encompasses the NPD process and the safety management tools and methodologies used in new product development, and it has a positive causal relationship with product quality (Calantone and Benedetto, 1988; Millson and Wilemon, 2008; Song and Parry, 1997). Safety practitioners have suggested that the issue of product safety should be addressed in parallel with the design process; however, much of the literature lacks an integrated view of product safety management methodologies and tools in the NPD process.

While it seems self-evident that safety-oriented NPD activities should lead to greater product quality, the individual components constituting the artifacts of safety orientation and the direct consequence of product safety performance (rather than the more generic product quality) could still benefit from disentanglement. Hence, in parallel to hypothesis 7, we propose:

H8. Design-for-Safety has a positive effect on Product Safety Performance.

Fig. 1 displays the resulting research framework.

4. Research methodology

4.1. *Data collection*

Our empirical study uses a sample of primary data that was collected from senior quality and innovation managers who have intimate knowledge about product development and safety performance of their company's products in the toy and juvenile products industry. One of the authors was kindly granted access by the China Toy and Juvenile Products Association (TJPA) to interview and collect data via a pre-defined survey at two of the largest industry-wide conferences organized by TJPA in Beijing (September 2008) and Hangzhou (October 2008). Attendees at this conference represented companies selling about 85% of all toys and juvenile products sold worldwide, either through Chinese domestic manufacturers or foreign multinational companies (European Commission, 2008). In this setting, we had detailed structured research interviews with 40 managers from 33 companies. All interviews were recorded in writing, and feedback on the minutes was solicited from the interviewees. All the records were anonymized for later analysis, a precondition which allowed us to discuss confidential and sometimes sensitive aspects of product quality and innovation. Using a global directory of toy manufacturers, we sent the same questionnaire to juvenile product manufacturers outside China, and 31 usable responses were returned.

In total, we received 255 usable responses from 126 firms in the two surveys. Table 1 shows the demographics of the survey sample by respondents and firms. All of the 255 managers responding via the survey had senior product development or quality management roles. The companies' sales revenues for the target period ranged from $5 million to $5.9 billion, totaling up to $11 billion, or 43% of global sales in the industry in 2008. Among these firms, 36 were fully owned foreign firms from the United States, Europe, Japan, Australia, and New Zealand, and 90 firms were either local Chinese firms or joint ventures. As China has a 70% share of the worldwide toy trade (TJPA website), the return rates between China-based and international firms are comparable.

To ensure the comparability of the survey data used in this analysis, several preliminary tests of significance were carried out using MANOVA with the five constructs (MCS, PSC, CE, DFS and PSP) as dependent variables and respondent manager type, firm size, country, and survey time as categorical independent variables. There were no significant mean differences of the five constructs by respondent manager type, country, and survey time. We checked for consistency of the responses by company or group, and observed no significant differences.

Table 2
CFA factor loading estimates and t-value (n=255).

Code	Questions/construct	loading	*t*-value
MCS	***Top Management Commitment to Safety* (*latent variable*)**		
TM1	*Extent to which top management assumes responsibility for product safety performance*		
TM2	Degree to which top management supports product safety management	.69	_a
TM3	Extent to which relevant department heads are evaluated on product safety performance	.75	10.97
TM4	Degree to which management participates in product safety improvement	.80	11.70
TM5	Degree to which management establishes product safety policies and objectives	.78	11.44
TM6	Specificity of firm's product safety policies and objectives	.81	11.71
TM7	Importance attached to product safety in relation to cost and schedule by top management	.79	11.51
TM8	Amount of review for product safety issues in top management review meetings	.71	10.39
PSC	***Product Safety Culture* (*latent variable*)**		
PSC1	Degree to which NPD engineers are familiar with relevant product safety standards and regulatory requirements	.76	_a
PSC2	Product safety is more important than cost and schedule in NPD process	.68	10.59
PSC3	Product safety review team independent of NPD project team conducts product safety review	.73	11.15
PSC4	Product safety review team has the authority to stop or postpone NPD projects	.72	10.94
PSC5	Degree to which product safety is considered by NPD engineers in NPD process	.81	11.30
CE	***Concurrent Engineering* (*latent variable*)**		
CE1	Cross functional teams are used in the NPD process	.62	_a
CE2	NPD project team leader and members remain on the project from beginning to end and not just for a short while or a single phase	.83	7.59
CE3	The NPD teams are accountable for their project's end results	.86	7.81
CE4	NPD team members share information via a central information system	.73	6.83
CE5	*Customer is involved in NPD process*		
CE6	Degree to which major suppliers are involved in the NPD process	.61	6.85
CE7	Degree to which product manufacturability is considered by design engineers during NPD	.65	7.04
DFS	***Design-for-Safety* (*latent variable*)**		
NPP1	A systematic NPD process (such as stage-gate, from idea generation, feasibility study, prototyping, pilot run, to mass production) is implemented	.72	_a
NPP2	The firm has clearly defined requirements for product safety and verification plans at each stage in the NPD process	.75	11.68
NPP3	Degree to which comprehensive product safety tests and reliability tests (internal or external) are carried out before product launch for production	.66	9.81
NPP4	Degree to which comprehensive product safety reviews (including hazard analysis and foreseeable misuse/abuse analysis) are carried out before product launch for production	.78	11.86
NPP5	In the NPD process, FMEA (Failure Mode Effect Analysis) is carried out for risk analysis	.63	10.87
NPP6	*Degree to which field/consumer tests are carried out before product launch for production*		
NPP7	Design reviews are carried out before new product launch	.71	9.53
NPP8	*Degree to which post launch reviews are carried out systematically*		
PSP	***Product Safety Performance (latent variable)***		
PSP1	In outgoing product audits, firm's assessment on product safety performance is:	.83	_a
PSP2	Customers' assessment on firm's product safety performance in the market is:	.73	8.54

Note: Items underlined (TM1, CE5, NPP6, NPP8) were deleted in the analysis due to poor model fit; a=not estimated when loading set to fixed value of 1.0; Model fit indices after deleting the four items: $P<0.001$, $\chi^2=2570.33$, $df=291$, $\chi^2/df=1.96$, RMSEA=0.06, CFI=0.92, IFI=0.92, TLI=0.90, AIC=742.33, saturated AIC=754.00, independent AIC=3691.20.

4.2. *The survey instrument*

The study's survey instrument was developed through extensive review of published questions in prior literature and feedback on initial versions of the survey from selected practitioners. The survey covers questions for the five constructs in the conceptual model and background information about the companies (see Table 2 for survey questions). Adequate constructs for product safety management were lacking, so we adapted those from the major quality management dimensions identified by Saraph et al. (1989) with modification from “quality” to “product safety.” In the CE and DFS sections, we incorporated relevant NPD practices identified by Cooper et al. (2004) and Koufteros and Marcoulides (2006). We also included safety management tools in NPD and solicited feedback from additional experts in the industry for validating our survey instrument. Product safety performance is measured both from the internal perspective (i.e., how product safety satisfies the company's internal requirements) as the outgoing product audit results by the company, and the external perspective as the customer's assessment or satisfaction with product safety performance. Third-party independent data such as accident/death rates and recall numbers were not available at this level.

A professional translator translated the original English survey questionnaire from English to Chinese, and another translator translated it back from Chinese to English. One of the paper's authors is bilingual in Chinese and English and verified the translation with minor changes to the questionnaire. A pilot survey was carried out with respondents from 22 juvenile product firms in Jiangsu province, China. Based on the pilot data and suggestions from experts in the industry, some items were removed from the initial survey.

The data collected are self-reported and represent the managers' perceptions within their product category or business unit. Respondents were required to rate the predictor variables on a five-point Likert scale (1=not at all, 5=to a great extent) and dependent variables (product safety performance) between 1 and 10 (where 1=strongly dissatisfied, 6=acceptable, 10=strongly satisfied). When the measures of predictors and criteria variables are rated by the same respondent, common method bias might exist. To address this problem, we followed recommendations by Podsakoff et al. (2003):

1) Application of all procedural remedies for questionnaire design;
2) Separation of criterion and predictor variables proximally and psychologically, with criterion and predictor variables on different pages;
3) Response anonymity and confidentiality were guaranteed during the survey;
4) Different scaling formats for the independent variables and dependent variables in the survey.

In the single-factor analysis for independent and dependent variables, 17 factors accounted for 85% of variance yielded and factor #1 accounted for 39% of variance. Since neither a single factor nor a general factor accounted for the majority of covariance in the measure, common method bias is unlikely to be an issue in the data (Podsakoff and Organ, 1986). Table 2 shows the CFA factor loading estimates and *t*-values.

4.3. Model analysis

We applied a two-step approach to formulate and test the model (Hair et al., 2010; Koufteros and Marcoulides, 2006), meaning that the measurement model is tested prior to the testing of the structural model to avoid possible interactions between measurement and structural models. In addition, confirmatory factor analysis (CFA) was performed on the entire set of items simultaneously (Anderson et al., 1987). SPSS 18 and AMOS 18 were used for data analysis.

The initial measurement model with the instrument of 30 items indicated an inadequate model fit. Model fit was improved for the measurement model through iteration of standard CFA refinement procedures (Hair et al., 2010). A good model fit was achieved after reducing the scale items from 30 to 26 in the five constructs (see Table 2). The items deleted include TM1 from MCS, CE5 from CE and NPP6 and NPP8 from DFS. Before each deletion, the specific item and its relevant construct were reviewed to ensure the integrity of the construct.

The fit indices used to evaluate the structural model are relative chi-square (the ratio of chi-square to degree of freedom, CMIN/DF), Comparative Fit Index (CFI), Incremental Fit Index (IFI), Tucker and Lewis Index (TLI), Akaike's Information Criteria (AIC), and Root Mean Square Error of Approximation (RMSEA). These indices were applied in view of their widespread use in model fit assessment (Hair et al., 2010; Marcoulides and Hershberger, 1997). Detailed criteria for analyzing model fit with these fit indices can be found in Byrne (1998), Hair et al. (2010), Hu and Bentler (1999), and Raykov and Marcoulides (2000). Relative chi-square values less than 3.0 imply an acceptable fit, and less than 2.0 is considered very good (Carmines and McIver, 1981). Browne and Cudeck (1993) suggested that RMSEA values of 0.08 or less indicate a reasonable model fit, and values less than 0.05 imply a good model fit. As a rule of thumb, values of CFI, IFI, and TLI close to 1 (e.g. > 0.9) indicate a very good model fit (Raykov and Marcoulides, 2000).

Content validity was ensured through a comprehensive literature review and a detailed evaluation by professionals from industry and academia. Most of the practices adapted in this research were tested in previous literature (Cooper et al., 2004; Koufteros et al., 2001; Saraph et al., 1989). Moreover, criterion-related validity (also called predictive validity or external validity) was verified through correlations between the factor scores for each construct (Nunnally, 1978) (see Table 3).

Table 2 shows the CFA factor loading estimates and t-values, which indicate that all factor loadings are highly significant as required for convergent validity, i.e. the extent to which the indicators of a construct share a high proportion of variance (Hair et al., 2010), and can be assessed by means of factor loadings through *t*-tests (Anderson and Gerbing, 1988). There is good construct validity if the standardized factor loadings are over 0.5 (ideally, 0.7 or higher) and significant at a confidence level of 95%, which requires t-values over 1.96. An alternative to evaluate convergent validity is through Average Variance Extracted (AVE), in which values of 0.5 or higher indicate adequate convergence. Convergent validity of our measurement model was supported with all AVE exceeding the guideline of 50% (see Table 3).

The construct reliability estimates and reliability coefficient (Cronbach's Alpha) are calculated to assess the reliability of the constructs (see Table 3). It ranges from 0.615 for PSP to 0.913 for MCS, thereby exceeding the minimum guideline of 0.6. Additionally, the reliability coefficient (Cronbach's Alpha) for all the scales ranges from 0.754 to 0.911 (refer to Table 3). Traditionally, reliability coefficients of 0.70 or higher are considered satisfactory (Nunnally, 1978); therefore, the scales are judged to be reliable. In sum, the above calculations offer strong support for the convergent validity of the measurement model.

Discriminant validity indicates the extent to which a construct is truly distinct from other constructs both in terms of how much it correlates with other constructs and how distinctly measured variables represent only this single construct (Bagozzi et al., 1991; Hair et al., 2010). Therefore, high scale correlations warrant a careful discriminant validity assessment for the constructs. First, discriminant validity was verified with Anderson and Gerbing's (1988) methodology with 1 not included in any of the confidence intervals for the constructs (see Table 3). Second, statistically different constructs exhibit interscale correlations that are adequately different from 1 (Bagozzi et al., 1991), which is the case in our constructs. The Cronbach reliability coefficients and average interscale correlations are presented in Table 3 and show that the Cronbach reliability coefficient for each construct is larger than its corresponding average interscale correlations. Hence, the model also passes the test of discriminant validity (Ghiselli et al., 1981).

Multiple group analysis is a structural equation modeling (SEM) framework to test differences between similar models for different group of respondents (Hair et al., 2010). To evaluate whether R&D intensity moderates the relationship in the proposed model, multi-group analysis was performed by splitting the sample between respondents representing firms reporting high and low levels of R&D intensity (calculated as the ratio of R&D expenses to

Table 3
Descriptive statistics, correlations, Cronbach's α.

	Mean	**SD**	α	**AVIC**	**MCS**	**PSC**	**CE**	**DFS**	**PSP**
Management Commitment to Safety	26.94	5.55	.911	.632	1.00				
Product Safety Culture	18.68	3.86	.842	.748	.71* .63-.79Δ	1.00			
Concurrent Engineering	21.91	4.26	.834	.672	.55* .45-.65	.84* .72-.96	1.00		
Design-for-Safety	32.79	4.33	.848	.765	.77* .67-.87	.86* .76-.96	.77* .63-.91	1.00	
Product Safety Performance	14.97	2.51	.754	.568	.50* .38-.62	.58* .44-.72	.53* .37-.69	.66* .50-.84	1.00
Construct validity (%)					58.0	54.8	52.7	50.8	61
Average variance extracted					0.913	0.849	0.855	0.865	0.615

Note: AVIC=Average Interscale Correlations; Δ: confidence interval for constructs.

* Correlation is significant at $p < 0.001$ level (two-tailed).

sales). Respondents from firms with a ratio of less than 3% are classified as Group A (n=116), and respondents from firms with a ratio equal to or above 3% are categorized as Group B (n=139). Applying methods used by Byrne (1998), Hair et al. (2010), Koufteros et al. (2006), Schumacker and Marcoulides (1998), we verified measurement invariance (or measurement equivalence), a step that is considered a prerequisite prior to assessing invariance for individual path coefficients. We selected the two-group methodology because Ahire and Dreyfus (2000); Calantone et al. (2003), and Koufteros and Marcoulides (2006) demonstrated in similar studies that this device is more appropriate to evaluate moderator effect compared to an approach in which environmental effects are posited as direct effects. We followed the six-stage procedure proposed by Hair et al. (2010) in conducting our multi-group analysis.

4.4. Structural model and hypothesis testing

As the measurement model showed a good model fit with construct validity and reliability, we proceeded to test the hypotheses with path estimates and t-values. The model fit indices (CMIN/DF, CFI, IFI, TLI, and RMSEA) were calculated and evaluated. As the model fits the data adequately, the t-values of the structural coefficients were used to test the hypotheses. The outputs of the standardized regression weights from the SEM analysis are presented in Fig. 2. A significance level of 0.05 was used to test the hypotheses. The main advantage of SEM analysis over conventional regression is its ability to decompose the observed empirical correlation or covariance between any two variables into three components: direct, indirect, and unexplained effects (Land, 1969). The decomposed path model effects are shown in Table 4.

Hypotheses 1 and 3 propose that management commitment to safety has a positive effect on product safety culture and Design-for-Safety, respectively. These two hypotheses were supported. Hypothesis 2 states that management commitment to safety has a positive effect on CE. This hypothesis was not supported because the *p* value is 0.25. There was no significant effect between management commitment to safety and CE. Not only was the relationship insignificant, the effect was also negative. Hypotheses 4 and 5 propose that product safety culture in NPD has a positive effect on CE and Design-for-Safety, respectively. The results support that a higher level of product safety culture was related to a higher level of Concurrent Engineering ($p<0.001$, C.R.=6.26) and Design-for-Safety ($p<0.01$, C.R.=3.16). Hypotheses 6 and 7 predict that CE has a positive effect on Design-for-Safety and product safety performance, respectively. With *p* values of 0.08 and 0.64, respectively, Hypotheses 6 and 7 were not supported at a significance level of 0.05. Therefore, CE does not have significant impact on Design-for-Safety and product safety performance. Hypothesis 8 proposes that Design-for-Safety has a positive effect on product safety performance. A variance of 61% for product safety performance was explained by Design-for-Safety, and this hypothesis was supported with *p* value of less than 0.001 and a C. R. of 4.68.

4.5. Testing for moderating impact of R&D intensity

Although five out of the eight hypotheses were supported, it is unclear if the relationships hold across different environments. For example, do the model relationships vary across firms with low and high R&D intensity? Adequate funding is a critical input to the NPD process and product safety management. Therefore, it is worthwhile to evaluate whether the hypothesized relationships are moderated by R&D intensity. The relationship between R&D intensity and firm or innovation performance has been empirically researched by Deeds (2001), Greve (2003), and Parthasarthy and Hammond (2002) with inconsistent results. Stock et al. (2001) found an inverted-U relationship between R&D intensity and NPD performance, and Bougrain and Haudeville (2002) claimed that R&D intensity does not influence the future prospects of a project. Still, high levels of R&D intensity are not necessarily linked to good innovation practice: they may simply mask process inefficiencies (Cebon and Newton, 1999; Dodgson and Hinze, 2000). Whatever the reasons, the resources available for managing NPD processes and product safety are different for firms with low and high R&D intensity; hence, we decided to determine whether the investigated relationships are different in firms with high R&D intensity compared to those with low R&D intensity.

We follow the approach of Hair et al. (2010) in testing the moderating effect of R&D intensity on the relationships in the model. The first stage verifies configural invariance, i.e. the same basic factor structure exists in all of the groups. This model is a totally free multiple group model (Model 1 or TF model) as all free parameters are estimated separately and are therefore free to take on different values in each group. No equality constraints are specified across groups. The TF model becomes the baseline model for comparison. The appropriateness of the posited structure depends on the overall or aggregate model fit. The second stage is to form groups based on a particular characteristic of interest and test metric invariance. Since we examine R&D intensity, we form groups based on the ratio of R&D expenses to sales. Firms with a ratio less than 3% are classified as Group A ($n=116$); whereas,

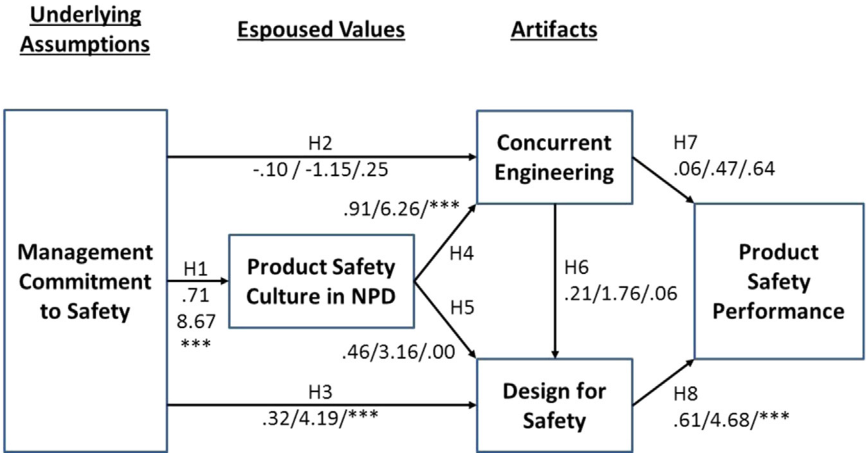

Fig. 2. Structural model. Note: Std. regression weight/*t* value/*p* value, Model fit indices: CMIN/DF=1.96, CFI=.92, IFI=.92, TLI=.90, RMSEA=0.06. R square values: Product Safety Culture (0.51), Concurrent Engineering (0.71), Design-for-Safety (0.81), Product Safety Performance (0.43).

Table 4
Summary of effects in the structural model.

	Direct effect	Indirect effect	Total effect	Correlation	Std. direct effect	Std. indirect effect	Std. total effect
PSC							
Effect of MCS	.71	.00	.71	.71	.71	.00	.71
CE							
Effect of MCS	−.12	.78	.66	.55	−.10	.65	.55
Effect of PSC	1.10	.00	1.10	.84	.91	.00	.91
DFS							
Effect of MCS	.36	.49	.86	.77	.32	.45	.77
Effect of PSC	.51	.21	.73	.86	.46	.19	.65
Effect of CE	.19	.00	.19	.77	.21	.00	.21
PSP							
Effect of MCS	.00	.96	.96	.50	.00	.50	.50
Effect of PSC	.00	.87	.87	.58	.00	.45	.45
Effect of CE	.10	.20	.30	.53	.06	.13	.19
Effect of DFS	1.05	.00	1.05	.66	.61	.00	.61

firms with a ratio equal to or above 3% are categorized as Group B ($n = 139$). We impose equality constraints on factor loadings for the observed dependent and independent variables across groups (Model 2). This is a critical test of invariance, and the degree to which this is met determines cross-group validity beyond the basic factor structure. A chi-square (χ^2) difference between Model 1 and Model 2 indicates whether the loadings are invariant across the two groups. When measurement invariance is established, the structural model estimate is evaluated for moderation by a comparison of group models. The TF model is estimated with path estimates calculated separately for both groups. The χ^2 difference test is conducted when the path estimates are constrained to be equal. If the models are statistically significant after constraining the path estimates, moderating effects exist.

Table 5 shows the results of the measurement invariance tests based on the above procedure. Configural invariance was verified as the separate models for respondents from low and high R&D intensity firms both exhibited an acceptable level of model fit ($\chi^2/\mathrm{d}f < 2.0$, RMSEA$=$0.06, CFI$=$0.86). Model 1 was compared to Model 2 and the chi-square difference is 24.17 with 21 degree of freedom and a p value of 0.29, which is not statistically significant. Thus, the two models exhibit full metric invariance, which means that the same five factors and factor loadings for specific items measuring each factor are invariant for respondents from low and high R&D intensity firms.

We applied the same procedure in setting up a two-group structural model to specify the two-group CFA model testing for differences according to R&D intensity. The unconstrained TF model estimates an identical structural model in both groups simultaneously, and the second group model is estimated by constraining the eight construct paths to be equal in both groups. The fit indices and path estimates are presented in Tables 6 and 7. Both models indicate an acceptable model fit. The chi-square difference was 2.78 with 8 degrees of freedom, which is statistically insignificant, with a p value of 0.95. This means that R&D intensity does not moderate the relationship in the structural model; therefore, the hypothesis that R&D intensity mattered was rejected. The path model relationships are invariant across firms with low and high levels of R&D intensity.

Table 5
Measurement invariance tests for low and high R&D intensity.

Model tested	χ^2	df	χ^2/df	RMSEA	CFI	Δdf	$\Delta\chi^2$	p
Unconstrained (model 1)	1043.77	578	1.81	.06	.86			
Measurement weights (model 2)	1067.94	599	1.78	.06	.86	21	24.17	.29

Table 6
Testing for R&D intensity as a moderator in the structural model.

Model tested	χ^2	df	χ^2/df	RMSEA	CFI	$\Delta\chi^2$	Δdf	p
Unconstrained	1043.87	582	1.79	.06	.87			
Equality of path estimates	1046.66	590	1.77	.06	.87	2.78	8	.95

We also used Doll et al. (1998) to test for multi-group invariance. A two-group model with equality constraints imposed for each path coefficient across the groups was executed, and the chi-square value was recorded. Next, the equality constraints for the path coefficients were relaxed one at a time. Chi-square difference was used to check for statistical significance. The results (Table 8) show that none of the path coefficients were statistically significant across the groups with low and high R&D intensity. The results are in line with those obtained with the approach previously reported.

4.6. The mediating effect of DFS on CE and PSP

Since the insignificant relationship between Concurrent Engineering and product safety performance seems contradictory to the literature, the mediating effect of DFS on CE and PSP deserves thorough evaluation. If the relationship between two constructs remains significant and unchanged once a third construct is introduced into the model as an additional predictor, a mediating effect does not exist (Hair et al., 2010). If the effect is reduced but remains significant after a third construct is added as a predictor, partial mediation is supported. If the effect is reduced to a point where it is not statistically significant after a third construct is included as an additional predictor, full mediation is supported. In order to evaluate the mediating effect of DFS between CE and PSP, we first verify that all three constructs were significantly correlated (see Table 3). In the next step we estimate the model without DFS presented. The model fit indices showed a good fit with normed Chi-square$=$1.88, CFI$=$.94, and RMSEA$=$0.06 (see Table 9). The path between CE and PSP also showed a significant relationship with C.R. of 5.79 ($p < 0.001$ level), with a direct effect of 0.57. The model was then estimated again by adding DFS to the model as a mediator between CE and PSP. The model fit indices changed slightly but still showed a good fit between the model and the data, with normed Chi-square$=$1.96, CFI$=$0.92, and RMSEA$=$0.06. The path between CE and PSP was no longer significant after introducing the mediating construct DFS, and the standardized regression weight dropped from 0.57 to 0.06 (total effect 0.19, indirect effect 0.13). Consequently, the full mediating effect of DFS on the relationship between CE and PSP was

Table 7
Path estimates for constrained and unconstrained models.

Path	P(a)	Unconstrained Estimates(a)	P (b)	Estimates(b)	p	Constrained Estimate(a)	Estimate(b)
MCS- > PSC	***	.64	***	.77	***	.64	.77
MCS- > CE	.32	−.12	.52	−.09	.23	−.10	−.12
PSC- > CE	***	.92	***	.88	***	.90	.91
MCS- > DFS	.02	.26	***	.40	***	.30	.35
PSC- > DFS	.04	.47	.01	.46	***	.49	.48
CE- > DFS	.18	.26	.25	.15	.08	.19	.19
CE- > PSP	.94	.02	.49	.12	.58	.08	.06
DFS- > PSP	***	.72	.00	.50	***	.65	.56

Table 9
Testing for mediation in the structural model.

Model Element	Model without DFS	Model with DFS
Model fit		
χ^2 (chi-square)	312.34	570.33
df (degree of freedom)	166	291
χ^2/df	1.88	1.96
Probability	0.00	0.00
RMSEA	0.06	0.06
CFI	0.94	0.92
Standardized parameter estimates		
MCS- > PSC	0.71*	0.71*
MCS- > CE	−0.08	−0.10
PSC- > CE	0.91*	0.91*
MCS- > DFS		0.32*
PSC- > DFS		0.46*
CE- > DFS		0.21**
CE- > PSP	0.57*	0.06
DFS- > PSP		0.61*

* significant at 0.01 level;
** significant at 0.1 level.

supported, meaning CE influences PSP through the mediator DFS. This explains why the direct relationship between CE and PSP is not significant in the structural model.

5. Discussion

The results of SEM analysis indicate that management commitment to safety has a great impact on product safety culture and Design-for-Safety (with an indirect coefficient of 0.5, the strong indirect effect between management commitment to safety and product safety performance is apparent). The results empirically confirm the claim in the literature that top management's support to product safety plays an important role in product safety (Eads and Reuter, 1983; Roland and Moriarty, 1983). They are consistent with White and Pomponi's (2003) finding that firms with a safety-oriented strategy achieve better product safety performance.

These findings are perhaps somewhat predictable given related results conceptually anchored in the literature, but our research confirms that these relationships are also carried by means of embedded practices in NPD. Our analysis showed that the relationship between product safety culture and CE and Design-for-Safety is strongly supported, and a strong indirect relationship between product safety culture and product safety performance was also observed in the SEM analysis, with an indirect effect of 0.45. This is in agreement with literature on product safety culture being critical for product safety (European Commission, 2008; Svenson, 1984; White and Pomponi, 2003).

The positive relationship predicted between Design-for-Safety and product safety performance is also strongly supported, as 61% of variance for product safety performance can be explained by Design-for-Safety. This finding is largely in line with previous findings that approximately 70% of product safety recalls were rooted in product design (Beamish and Bapuji, 2008; White and Pomponi, 2003).

Contrary to what was predicted, there was no significant relationship between management commitment to safety and Concurrent Engineering. Concurrent Engineering is often associated with shortened time-to-market, with cycle time the key and often sole performance indicator (Gerwin and Barrowman, 2002). However, time-to-market and product safety are often competing goals, and firms with a strong focus on product safety may not necessarily consider Concurrent Engineering as a practice to enhance product safety.

Neither did we find a significant effect of Concurrent Engineering on Design-for-Safety and product safety performance, which was unexpected because empirical studies reported the use of CE teams having a positive effect on product quality performance (Koufteros, et al., 2002; Koufteros and Marcoulides, 2006; Sethi, 2000). There are five possible explanations:

1. The mediating effect of DFS: based on the analysis in Section 4.6, the relationship between CE and PSP is fully mediated by DFS;
2. Mutual exclusive perception of the impact of CE on cycle time and product safety;
3. Industry specificity: juvenile products are not very complicated,

Table 8
Testing for moderating effect of R&D intensity in the structural model.

Model tested	χ^2	*df*	χ^2/df	RMSEA	CFI	$\Delta\chi^2$	Δdf	*p*
Constrained model (all invariance)	1136.52	634	1.79	.06	.84			
MCS- > DFS (path invariance relaxed)	1137.58	635	1.79	.06	.85	1.06	1	.30
MCS- > CE (path invariance relaxed)	1136.52	635	1.79	.06	.85	.00	1	.99
PSC- > DFS (path invariance relaxed)	1137.53	635	1.79	.06	.84	.01	1	.93
MCS- > PSC (path invariance relaxed)	1139.32	635	1.79	.06	.84	2.8	1	.09
PSC- > CE (path invariance relaxed)	1136.84	635	1.79	.06	.84	.32	1	.57
CE- > PSP (path invariance relaxed)	1136.81	635	1.79	.06	.84	.30	1	.59
DFS- > PSP (path invariance relaxed)	1137.66	635	1.79	.06	.84	1.16	1	.28
CE- > DFS (path invariance relaxed)	1137.17	635	1.79	.06	.84	.66	1	.42

and most of the product-related hazards have been captured by regulatory standards. Hazards or safety issues can still be detected during product safety tests and hazard analysis at a later stage, even if product safety engineers are not involved at an early stage in the NPD. Therefore, the use of CE is not necessarily linked with better product safety performance;

4. As CE is used widely by most firms, it is no longer a competitive differentiator. This finding echoes earlier studies such as Clark and Fujimoto (1991), who found that CE used in incremental projects decreased product quality, or Koufteros et al. (2001) who did not find any significant direct relationship between CE and quality;
5. As some of the interviewees mentioned in our in-depth interviews, even if different groups participate during NPD in the early stages, in reality, different functions still focus on quite different aspects of the product. One of the interviewees commented, Concurrent Engineering “smooths the launch. I don't think it will have impact on the safety of the products because different groups focus on different things. For example, manufacturing people are mainly interested in the timing, how to produce it, how to assemble it; purchasing people are mainly interested in communicating with suppliers, starting ordering the material…. I really don't think it will have impact on the safety of the product as much as on the commercial side…to launch it smoother.”

6. Conclusions and implications

6.1. Summary of results

This paper pursued the questions of which NPD aspects lead to greater product safety and how does organizational culture influence NPD practices and product safety. Based on a survey of 255 quality and engineering managers in 126 firms in the juvenile products industry, we extend the literature with an empirical analysis of eight hypotheses linking organizational culture with new product development and product safety. Five out of eight hypotheses were supported, and R&D intensity was excluded as a moderating factor (see Table 10).

6.2. Theoretical implications

Grounded in organizational theory, this research contributes to the body of NPD and product safety management literature in several respects. First, we introduced and tested a conceptual framework for product safety management in NPD that integrates organizational culture, NPD practices, and safety management methodologies. The survey instrument and the structure model can be used as a foundation for further study of product safety in NPD.

Second, previous literature had not addressed how product safety is best achieved as a result of optimized NPD policies and practices. This research supplements the previous NPD and safety management studies by integrating the product safety dimension as a dependent variable and incorporating product safety management methodologies. Our model represents the first reported attempt to empirically investigate the relationships among the five constructs in a rigorous approach with an unparalleled primary data set collected worldwide.

Third, previous product safety literature mainly focused on the technical aspects and principles of safety management. Most of these studies were limited and prescriptive in nature. As a result, by integrating organizational culture with the Design-for-Safety techniques and practices, this research has advanced a systematic and holistic view on product safety and provided empirical evidence to support (or reject) earlier prescriptions in the safety literature.

Fourth, this study reveals that the use of CE has no direct relationship with product safety performance. The findings of this study rebut the recommendation that Concurrent Engineering should be used as a mechanism to ensure product safety. Further research into the causes of the absence of this effect is necessary, along with the possible explanations outlined in the discussion.

Finally, this research advances scientific understanding of innovation and NPD in the context of failure and product safety by looking at several factors that affect product safety in the product innovation process, which has always been a key activity in industry. However, if product safety is not well understood in relation to other key dimensions such as management commitment to safety, product safety culture, and the process of product innovation, random failure may be unavoidable.

Table 10
Summary of the hypothesis testing results.

H-#	**Hypotheses**	**Result**
1	MCS has a positive effect on PSC in NPD	Supported
2	MCS has a positive effect on CE	Not supported
3	MCS has a positive effect on DFS	Supported
4	PSC in NPD has a positive effect on CE	Supported
5	PSC in NPD has a positive effect on DFS	Supported
6	CE has a positive effect on DFS	Not supported
7	CE has a positive effect on PSP	Not supported
8	DFS has a positive effect on PSP	Supported

6.3. Managerial implications

Combining the present analysis with qualitative aspects of our research, we argue that the three pillars of product safety are top management commitment to safety, a safety-first culture, and a robust Design-for-Safety, and the managerial implications include the following:

1) Top management is the main driver of product safety, and with a safety-oriented strategy, management is in the position to commit necessary resources to implement best practices for safety management and make product safety a priority. NPD practices and product safety performance often varies between product categories and business units even within the same firm. Top management should “walk the talk” and get personally involved in product safety decisions.
2) Firms should build a product safety-oriented culture across the firm. Specifically, a firm should establish incentive programs to ensure all levels of employees understand the importance of product safety and position product safety as the firm's top priority. Technical employees (R&D, engineering, quality, and production, etc.) should be trained on relevant product safety standards and safety management tools. The quality team should be empowered to make decisions on product safety independently (e.g., through independent product safety review teams). R&D and engineering teams should be trained to know how to design product safety into products.
3) Firms ought to ensure a robust Design-for-Safety. Design-for-Safety is the only variable in the model that has a direct impact on product safety performance in product development. Therefore, manufacturers should implement an effective and efficient idea-to-launch process that is robust and controlled, and that emphasizes the quality of execution and, most importantly, incorporates professional safety management methodologies.

As for CE, there is no doubt it will shorten time-to-market in NPD; however, it is not a determinant factor for product safety. For companies intending to improve product safety, CE should not be the top priority.

6.4. Limitations and future research

This research focused on the juvenile products industry, which has a large manufacturing share in China. However, other industries are more regulated than the juvenile products industry (e.g., pharmaceuticals), and others may have a greater balance of geographical distribution of product design, development, and manufacturing. As the dynamics may look different in other industries, this research needs to be replicated across industries, across geographies, and, ideally, across time to ensure greater representation. In particular, time series analysis would be useful to permit the identification of causal relationships. Moreover, manufacturing accounts for a significant share of product safety issues, and future research should also investigate the effects of manufacturing practices on product safety through adding relevant constructs to the model.

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